THE ELECTRIC TRAMCAR HANDBOOK

FOR MOTORMEN, INSPECTORS, AND DEPÔT WORKERS

BY

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CONTENTS.

INTRODUCTION.

This handbook has been compiled with a view of bringing together, in convenient form, a simple description of modern electric tramcars, and to give instruction regarding the proper operation of these vehicles on the road.

The recent great development of electric tramway systems in this country has occasioned a wide-spread demand for capable and intelligent men to act as motormen, and in the car sheds and depôts of the various companies and corporations a large and increasing number of engineers and assistants find daily employment.

Information is given in the following pages which will be useful to men wishing to qualify for positions as motormen who are at present gaining practical experience in operating cars for the first time.

It will also be of assistance to those readers who are earning a livelihood at such work, and who desire to know more about the vehicles under their charge, with the view of becoming more expert at their work or securing promotion to better positions on the staff.

To men engaged in car depôts and repair sheds the chapters dealing with car equipments and apparatus will be of interest, as also the chapter relating to "faults and breakdowns," and may assist them to more fully understand the machinery under their care and indicate the precautions necessary to ensure its proper working.

In taking up the subject of electric cars the novice would be well advised to carefully read and master each chapter in the order given, otherwise he may find some difficulty in understanding the matter dealt with towards the end of the book and be needlessly discouraged from further effort.

Many people think electrical machinery so mysterious and complicated in action as to be quite beyond their understanding; while it must be admitted that some electrical appliances are rather complicated in construction, yet a great deal of the mystery vanishes when the simple fundamental laws which govern the electric current have been mastered and the knowledge thus gained made use of.

The first chapter of this handbook explains some of these laws relating to the current, and mentions the different effects to which the passage of a current may give rise when sent along a suitable "conductor."

Mention is also made of the methods of producing and controlling the electric current, and the meanings of the units volt, ampère, and ohm are explained in simple language.

Some motormen know nothing whatever beyond the actual manipulation of the platform handles, and yet are able to run their cars with safety and dispatch under ordinary circumstances; but when a breakdown occurs they are unable to effect a remedy, and if a defect develops in certain parts of the equipment may allow their cars to get beyond control, with disastrous consequences to all concerned.

A motorman of this class, who does everything in a mechanical fashion, cannot appreciate the possibilities of economically operating his car, and cannot understand the meaning and reason of the rules issued to him by his superiors.

It is evident that the more a man knows about his work the better is his chance of securing steady employment and better pay.

The best motorman is the one who understands the apparatus he is handling, and operates it as instructed by his employers, and in accordance with the dictates of common sense.

He must be physically strong enough to control the car under all conditions and to withstand the constant exposure to the weather on a car platform.

He is expected to keep himself mentally alert and capable of performing his duties without accident, and to this end must rigidly abstain from stimulants during working hours, and pay attention to the ordinary rules of health and good living.

A motorman, to be able to safely operate a heavy car through the crowded streets of one of our large cities, and on the severe grades and slippery tracks which often exist, must necessarily keep himself in fit condition, otherwise he risks being put aside for abler men, and may have to take up less exacting duties at a correspondingly less rate of pay.

Tramway managers are always ready to recognise good men and retain their services, while being just as anxious to get rid of ignorant and unsatisfactory men who are always in trouble.

The writer will be pleased to receive criticisms and suggestions for improvement in future editions, should such be called for, and he wishes to thank the British Thomson-Houston Company, the British Westinghouse Company, the Brush Electrical Engineering Company, the British Electric Car Company, Messrs. Dick, Kerr and Co., Messrs. Estler Bros., Messrs. Bruce, Peebles and Co., and other firms for their kindness in furnishing diagrams and descriptions of the various machines and fittings manufactured by them.

W. A. AGNEW.

CHAPTER I.

THE ELECTRIC CIRCUIT.

Conductors and Insulators.—To convey electricity to any distant point, a suitable conducting path must be provided along which it may travel.

If a continuous flow of current is required the conducting path must be arranged in a complete loop or circuit, so that the power may arrive back again at the generating point.

Many different materials are able to "conduct" electricity, but certain of these are better than others, as they offer comparatively little resistance to the passage of the current. Silver is the best conductor, but copper is most commonly used. Some metals and alloys offer great resistance to the current, and are only used where this property is found serviceable.

Materials which are unable to conduct electricity are termed **non-conductors** or **insulators.**

The insulators in general use are wood, indiarubber, asbestos, mica, cotton, paper, etc., and these are used when it is necessary to protect a conductor from leakage or to keep it from coming in contact with other conductors.

When a bare conductor is used it must be supported at intervals on suitable insulators. A familiar example of this is seen in telegraph or telephone lines.

When conductors are bunched together or are likely to touch other conductors, they are usually protected by a covering of insulating material.

Properties of the Current.—When electricity is flowing along a metallic conducting path it shows its presence in two ways:

(A) By heating its conductor.

(B) By a magnetic effect.

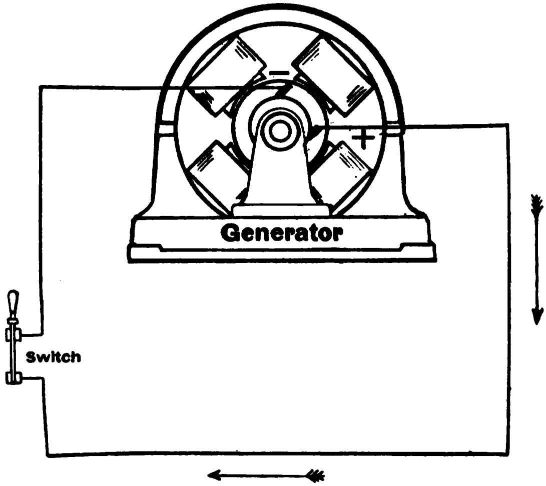
Heating Effect.—The first-noted property is taken advantage of to produce light, as in electric glow lamps,

and electric stoves are made in which the current is employed to produce the desired warmth.

The amount of heat produced in a conductor depends on its resistance and on the rate at which the current flows along it.

Magnetic Effect.—The magnetic effect produced by a current is easily shown by a simple experiment. Take a short bar of soft iron and coil round it some insulated wire. On passing a current through the wire the iron bar

Fig. 1.



Simple Electric Circuit.

will be rendered strongly magnetic and will attract iron or steel at both ends.

Such an arrangement is termed an **electro-magnet,** and the iron remains in the magnetic state so long as the current is kept circulating through the exciting coil; the magnetism vanishes almost completely when the current is stopped.

The magnetic effect of a current is usefully employed in many different machines and devices such as electric bells, telephones, electro-motors, etc.

Simple Circuit.—The diagram, Fig. 1, shows a simple electric **circuit,** in which the current circulates from the

positive terminal of the "generator" through the conducting path, in the direction of the arrows, to the **negative** terminal.

Electric Pressure.—If we measure the pressure which maintains the current in this simple circuit we find it is highest at the positive terminal, and gradually falls to zero at the negative end of the conducting path.

The "pressure" existing between two points of an electric conductor is measured in **volts**, and is sometimes called "voltage."

Resistance.—The reduction of pressure in the circuit is due to the **resistance** which the conductor offers to the flow of current, and the amount of resistance depends on the size of the conductor, on the length of the circuit, and on the material of which the conductor is composed. The "resistance" in a circuit is measured in **ohms**.

Current.—The rate at which a current flows through a circuit depends on the voltage existing between the ends, and on the amount of resistance offered by the conductor.

The "rate" of flow (sometimes called the strength of the current) is measured in **ampères.**

Generation of the Electric Current.—There are several methods by which electricity can be produced, but the only commercially successful way, so far, is to generate it by means of **dynamo-electric machines.**

Dynamo-electric machines, or "dynamos," depend for their operation on a simple fundamental principle first made known by Michael Faraday in 1831. This scientist discovered that when a complete conducting loop or coil was revolved before the poles of a magnet a current of electricity was generated in the coil and continued to flow as long as the motion of the coil was maintained.

Modern Generators.—In modern **dynamos** for producing continuous electric currents very powerful electromagnets are employed, and an **armature** carrying many coils of copper strip or wire is rapidly revolved between the poles of the magnets. The current generated in the revolving armature coils is brought to a **commutator** mounted on the same shaft, and is collected therefrom by metal or carbon **brushes** which press against the surface of the commutator. The current generated in the armature is alternating in direction, and the action of the commutator is to convert it into a current flowing in one direction only, hence the terms **continuous** or **direct** current.

The commutator usually consists of copper bars or **segments** built into drum form, each segment being connected to the ends of an armature coil and insulated from neighbouring segments, and also from the shaft, by strips of mica.

The whole commutator is bound firmly together, and is turned and polished to allow the collecting brushes to rub smoothly and closely on the revolving surface.

Complete Armature.—In Fig. 2 is shown a complete armature with commutator mounted on shaft and arranged to be driven by a belt from a steam engine or other source of power.

FIG. 2.

ARMATURE.

When such an armature is mounted and revolved between suitably shaped magnets it is able to furnish a continuous current of electricity.

A complete dynamo is shown in Fig. 3.

Generator or Motor.—An important point to note here is that a dynamo-electric machine can be used as a **generator** or as a **motor** as desired. If driven from a steam engine the machine will supply current, and if supplied with current from some other source it will run as a motor and be available for driving machinery.

This useful reversible property of the dynamo-electric machine is taken advantage of on electric cars in order to obtain an "electric brake" action, as will be seen later when the subject of brakes is discussed.

Field Magnet Connections.—The electro-magnets of a dynamo-electric machine—**field magnets** as they are

usually called—are excited by coils of insulated copper wire through which current is passed.

In some types of machines these coils consist of a few turns of heavy wire, and the whole of the armature current passes through them. This method of exciting the magnets is termed **series-winding,** and is generally employed in tram-car motors on account of the necessity of obtaining a

FIG. 3.

TRACTION GENERATOR.

strong effort from the motors to start the car and climb steep gradients.

In other machines the field-magnet coils consist of a large number of turns of comparatively small wire, and only a small portion of the armature current passes through the coils. This arrangement is called **shunt-winding,** and is used on motors which have to run at constant speed or for generators having steady loads.

A combination of shunt and series winding is used on some machines, and the field-magnets have two windings, one of thin wire, which takes a shunt current, and the other of thick wire, which carries the main armature current.

This arrangement is termed **compound-winding,** and is used for generators where the current taken from the machine varies widely, as in tramway work, etc., the effect of the series coils being to keep the voltage of the machine constant, or slightly increase it as the load becomes heavy.

Compound-winding is employed for motors where a strong effort is required for starting, as well as a steady speed when running.

Speed Regulation.—The pressure of the current supplied from a generator will depend on the speed at which it is driven and on the strength of its field-magnets.

Conversely, the speed of a motor depends on the pressure of the current with which it is supplied,and on the strength of its field-magnets.

Accordingly, where the speed of a motor has to be varied, arrangements must be made to vary either the pressure of the current or the strength of the field-magnets.

In the case of series-wound motors, as fitted to electric cars, the former arrangement is usually adopted.

Rheostats.—This varying of the supply voltage may be done by causing the current to go through a long length of wire or strip made of some material which offers great resistance to the passage of the current, thus reducing the pressure; such a device is called a resistance coil or **rheostat**, and is generally constructed of fireproof materials and divided into sections with terminals attached, so that the amount of resistance in use may be altered as required.

Reversing Motors.—To reverse an electro-motor it is necessary to change the direction in which the current flows through the armature or through the magnet coils. Fig. 4 explains how this reversal can be accomplished in a series wound motor.

In the first diagram (*a*) the current is flowing through the magnet coils and armature in the direction of the arrow heads, and the armature revolves in a certain direction.

In the second diagram (*b*) the current flows through the magnet coils as before, but the direction through the armature is changed, and it now revolves in the opposite direction.

Electric Car Reversing Gear.—In electric cars this changing of the armature connections is effected by a

reversing switch fitted in the controller, and operated by a small handle conveniently placed.

Motor "Back Pressure."—When an electro-motor is running it produces a "back pressure," depending on the speed of the armature and the strength of the magnets.

If a series wound motor has little or no work to perform it will run up to a high speed, in order that its back pressure may almost equal the voltage of the supply

FIG. 4.

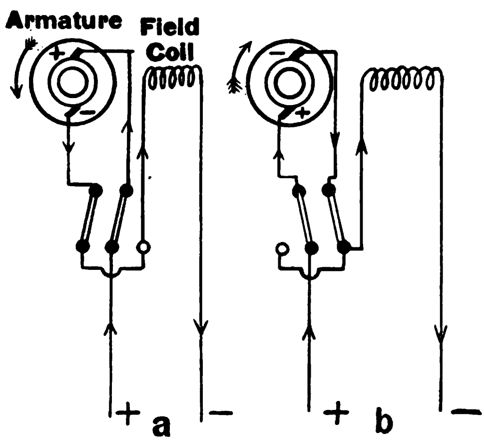


DIAGRAM OF REVERSING SWITCH.

current, and thus allow only a small amount of current to pass through the machine.

When the motor is heavily loaded and has to perform a large amount of work its speed drops, and the reduction in the back pressure which occurs will allow a greater current to flow through the motor in order to do the necessary work.

Starting Loaded Motors.—It will therefore be understood that if a motor is so heavily loaded as to prevent the armature from revolving, an enormous rush of current may pass through it, as no back pressure is being produced by the machine, and the supply current has only to overcome the comparatively slight resistance offered by the copper wire in the armature and field-magnet coils.

It is important that when heavily loaded motors have to be started, as on an electric car, the supply current should reach the motor terminals at a low pressure to begin with, and the pressure should be gradually increased as the car speeds up and the motor back pressure rises, in order to prevent damage to the machines by an excessive rush of current through the windings, which would make them red-hot and destroy the insulation.

Controllers.—This gradual switching-on of the current is effected by the **controller** fixed on the car platform and arranged in conjunction with a rheostat to effect the changes gradually and without jerks to the motors.

Switches.—When a gap or break is made in an electric circuit in which a current is circulating, a spark is produced at the point of rupture, and if only a small gap be provided a continuous spark or **arc** will be set up and will continue so long as the current circulates or until the contact points are burned away and the gap between increased. With powerful currents, such as are used in tramway work, this electric arc may prove very destructive, and accordingly means must be provided to break circuit very quickly, and to introduce a wide gap so that the spark is destroyed at once.

An apparatus for opening an electric circuit is termed a **switch,** and is generally fitted with an insulated handle to protect the operator from shock; by means of strong springs the circuit is broken as rapidly as possible, and the arc destroyed immediately.

A typical form of switch mounted on an insulating base is shown in Fig. 5.

In car controllers, or in switches not fitted with spring action, the operator must supply the necessary rapidity of action himself, and never break a heavy current slowly, as it may cause serious damage to the contacts of the apparatus.

Defective Circuits.—If a gap or break occurs in an electric circuit, due perhaps to the conductor breaking or working loose at some point, the current will cease to flow, and an **open circuit** is said to exist.

When normal conditions prevail in an electric circuit the current flows along its proper conducting channel, but should some easier path be provided offering less resistance the current will prefer to travel by it, and a **short circuit** is said to exist, or simply, a **short.**

When the protective covering of a conductor becomes damaged, and the bare conductor comes in contact with the ground or earth, or with some other conducting material connected to the negative side of the circuit, there is said to be a **ground** or **earth** on the circuit.

Useful Rules.—To find the resistance of a circuit it is necessary to divide the voltage existing between the ends of the circuit by the rate of the current in ampères.

Example: To send fifty ampères through a certain circuit

FIG. 5.

QUICK BREAK SWITCH.

it is found that the pressure necessary at the terminals 500 volts. What is the resistance of the circuit in ohms?

$$500 \div 50 = 10 \text{ ohms.—Ans.}$$

To find the voltage existing in a circuit the current in ampères should be multiplied by the resistance of the circuit in ohms.

Example: A current of fifty ampères is flowing through a circuit of ten ohms resistance.

What voltage exists between the terminals of the circuit?

$$50 \times 10 = 500 \text{ volts.—Ans.}$$

To find the rate of the current in ampères the pressure in volts between the terminals should be divided by the resistance in ohms.

Example: How many ampères will 500 volts send through a circuit which has a resistance of 10 ohms?

$$500 \div 10 = 50 \text{ ampères.—Ans.}$$

CHAPTER II.

SYSTEMS OF ELECTRIC TRACTION.

Different Systems.—Several different systems of supplying electric cars with current have been proposed and tried in practice, and may be classified as follows:

(*a*) Accumulator systems.
(*b*) Third-rail systems.
(*c*) Surface-contact systems.
(*d*) Conduit systems.
(*e*) Overhead trolley systems.

Accumulator System.—With this system each car is equipped with an electric storage battery or **accumulator,** which may be charged with current at the car depôt, and the car motors derive their supply of power from these accumulators.

The speed of the car may be controlled by connecting the individual cells of the battery in groups, and thus obtaining different voltages, or a rheostat may be used for the same purpose.

Each car forms an independent unit, and may be run anywhere on the line until its storage battery becomes exhausted and requires re-charging.

Up till the present time, however, accumulator systems have not proved satisfactory on account of the great weight of the batteries and the expense of keeping them in proper condition.

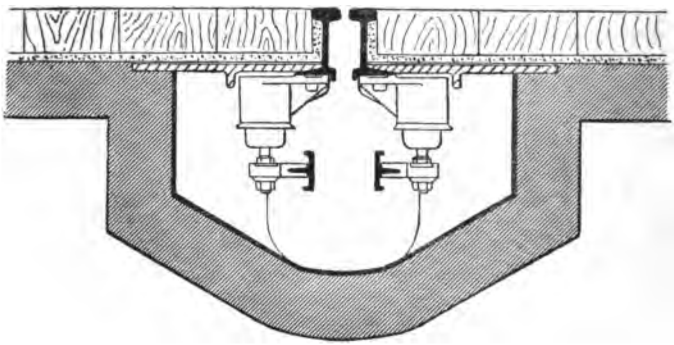
The vibration to which the cells are subjected on a street car, and the heavy duty they have to perform prove fatal to the longevity of the accumulator, thus rendering this attractive system of traction commercially impossible.

Third-rail System.—This system is suitable only where the line is fenced and private property, as the current is here brought to the car by a contact rail, which is mounted on insulators and fixed between or alongside

the track rails, and as the contact rail is quite exposed to the sight and touch it is not suitable for use on public streets.

For elevated lines and underground "tube" railways this system of traction is widely adopted, as in the Mersey Tunnel and Overhead Railway in Liverpool, and several of the underground lines in London. The current is collected from the third rail by a metal collecting-shoe or "skate," and after passing through the car motors returns to the generating station by the track rails or by another contact rail laid alongside.

FIG. 6.



CROSS-SECTION OF CONDUIT.

Surface Contact System.—In this system current is collected from small metal studs which automatically become "live" or charged with current when the car is immediately over them, and are switched out of service and become "dead" when the car has passed.

These contact studs are supplied by underground cables with current from a central power station.

To collect the power from the studs a long collecting "skate" is fitted under each car, and is arranged to rub against the tops of the studs, which project a little above the surface of the street. The current, after passing through the car motors and other apparatus, gets back to the power house by the track rails as usual.

This system is in use on a few lines in this country, and may be used more widely in the future as the design

and construction of the apparatus is improved and it is rendered more certain in action.

Conduit System.—This system derives its name from the fact that the conductors supplying power to the cars are fixed below the road surface in a shallow trench or **conduit,** the current being collected from them by a contact "plough" which is carried on the truck under the car, and passes down through a narrow slot provided in the top of the conduit.

A cross-section of a conduit is given in Fig. 6, and a car-truck fitted with collecting plough and the necessary gear is shown in Fig. 7.

It will be seen that two conductors are fixed in the conduit (one being used as a return), and that they are constructed of T-iron, and supported clear of the sides by insulators fixed at suitable distances along the trench.

Traps are provided at frequent intervals along the line to allow of the "plough" being withdrawn from the conduit when necessary, and the conduit is well drained to prevent rain-water accumulating and "short-circuiting" the conductors.

This system is employed on (some of) the tramways of the London County Council, and at Bournemouth, and may be used in conjunction with a trolley system—that is, the conduit may be used in the busy centre of a city where overhead wires are objected to, and the overhead trolley system may be used for outlying lines.

The cars in this case require to be equipped with both trolley pole and collecting plough, and at the junction of the two systems these are changed over as required.

Overhead Trolley System.—This system is most widely adopted in this country, and although by no means picturesque it possesses the merits of simplicity and cheapness of construction, together with ease of repair and manipulation.

With the trolley system the cars are supplied with current from a bare copper wire suspended overhead, the power being collected therefrom by a long pole fixed to the roof of each car and carrying a small metal "trolley" wheel, arranged to press against the live conductor and run smoothly along its under surface.

Usually a single trolley wire is fixed over each track, and the current, after passing through the car, returns to the power station bv the rails in the usual way.

Path of Current.—In Fig. 8 is given a diagram of the path of the current in the trolley system of electric traction.

Fig. 7.

Under Truck and Plough for Conduit System.

From the generating station the current is led by underground cables to section boxes or switch pillars situated at suitable points along the route, and after passing through switches the current reaches the overhead conductor, and can be collected by the running cars.

Circuit Breakers.—Each "feeder" cable leaving the power station is connected through an **automatic circuit-breaker,** a device which is arranged to cut off the current if it exceeds a certain safe maximum, and thus prevent damage being done to the cables and generating machinery.

FIG. 8.

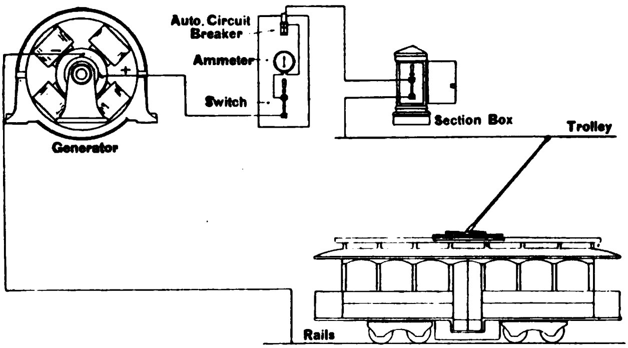
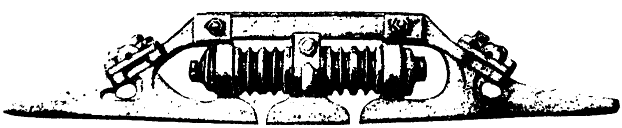


DIAGRAM OF CURRENT PATH, FROM POWER HOUSE TO CAR.

This excessive rush of current might be caused by the trolley wire falling on the track rails or by some defect occurring in a car equipment, or perhaps a leak might develop on the feeder cable itself owing to its protective covering becoming damaged.

FIG. 9.



ESTLER BROS.' SECTION-INSULATOR.

The "feeders" are usually laid in metal or earthenware pipes under the street surface, and manholes are arranged at intervals to allow of inspection or renewal being effected.

The overhead trolley wire is supported above the track at short intervals by insulating "hangers" and "ears," which are, in turn, supported either by span wires attached

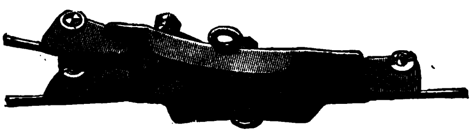
to side poles, or rosettes fixed to buildings, or by centre and side-bracket poles fixed near the track.

Section Insulators.—The trolley wire is divided into sections not exceeding half a mile in length by **section-insulators,** a type of which is shown in Fig. 9.

It will be noticed that the ends of the trolley wire are attached to the insulator, and that these ends are kept quite distinct and insulated from one another, and the current thus prevented from passing from one section of the line to the other.

The idea of fitting these insulators is to be able to locate faults or breakdowns which may occur on the line and prevent the entire system from being knocked out of service by some trifling mishap occurring at some point on the road.

Fig. 10.



Overhead Frog for Centre-running Trolley.

The division of the line into sections also permits of a fairly even voltage being maintained on each section.

Overhead Junctions.—Where points and crossings occur on the track it is necessary to provide suitable devices to keep the trolley wheel always in contact with the conductor and to guide it in the path taken by the car itself.

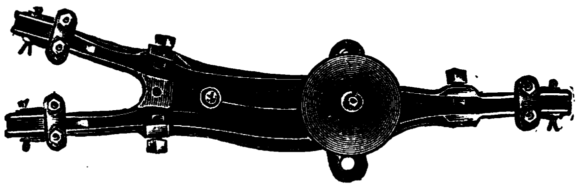
When the car is provided with a fixed or "centre-running" trolley head it is sufficient to provide these overhead crossings and frogs with suitable grooves and ridges to guide the trolley wheel in the proper direction (Fig. 10). When a side-running or "swivel-head" trolley is used the overhead gear has to be provided with movable tongues and guides so that a continuous and unbroken path is provided for the trolley wheel when changing from one conductor to another; otherwise the head might twist round and leave the wire.

An overhead frog, adapted for use with swivel-head trolleys, is shown in Fig. 11. In the next chapter both

centre and side-running trolley heads are illustrated and described.

Guard Wires.—Where there is a risk of telephone and telegraph wires falling across the "live" trolley wire and becoming charged with current, "guard-wires" are erected directly above the trolley wires, and are connected to the rails, so that if a wire falls and makes contact with both guard and trolley, a "ground" will be established, and in all probability the fallen wire will be fused through and will fall, harmless, to the street. If a number of wires were to fall at once, or if the guard-wire itself were to fall across the trolley wire, the resulting heavy rush of current to the rails would cause the automatic circuit-breaker in the power-station to open, and the current would thus be cut

FIG. 11.



MECHANICAL FROG FOR SWIVELLING TROLLEY.

off until such time as the fallen wires were removed and the "breaker" replaced.

It will be seen that the "guard" wires are simply employed to prevent falling wires from remaining "live" or charged, to the possible danger of pedestrians on the streets or passengers on the cars.

Precautions against Shocks.—It is important to note in this connection that the current supplied to electric cars is at a comparatively high pressure (500 volts), and considerable risk is run by anyone touching a conductor carrying such a voltage.

In the case of the trolley wire falling to the ground and remaining charged it must never be touched with the bare hand, but only with a dry stick or board, or, better still, by using rubber gloves to protect the hands.

Never catch hold of a live wire with a thin handkerchief or any damp material.

If a trolley wire falls in a busy thoroughfare it is

advisable to make it dead at once by drawing it firmly across the track rails and keeping it in contact with them until the repair gang or engineer arrives.

If, however, the wire falls in a street where there is little risk of anyone touching it, it may be held clear of the rails, to allow of the power being maintained on the line.

If a live wire is in contact with any person and he is unable to extricate himself, endeavour to draw him clear by pulling his clothing, if dry, but be careful not to touch his boots or skin when rendering assistance.

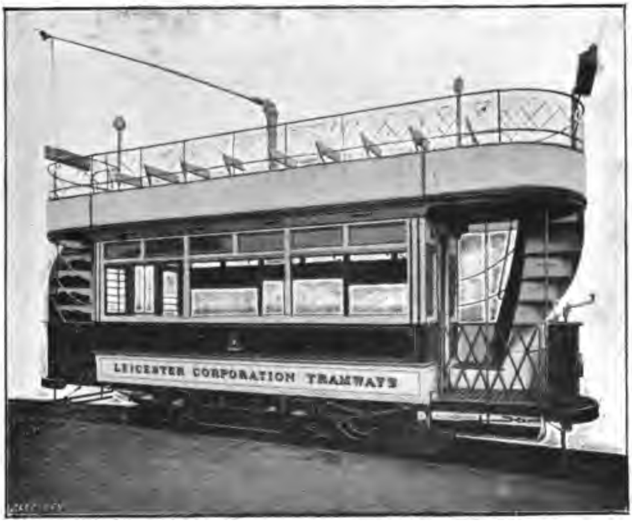
If unable to draw the person clear, the live wire should be pulled to the rail and rendered dead as previously described, or the power should at once be switched off at the nearest section box.

CHAPTER III.

ELECTRIC CARS.

Types of Cars.—Several different types of cars are in use in this country, some of the single-deck form, and others arranged to also seat passengers on the top. The

FIG. 12.



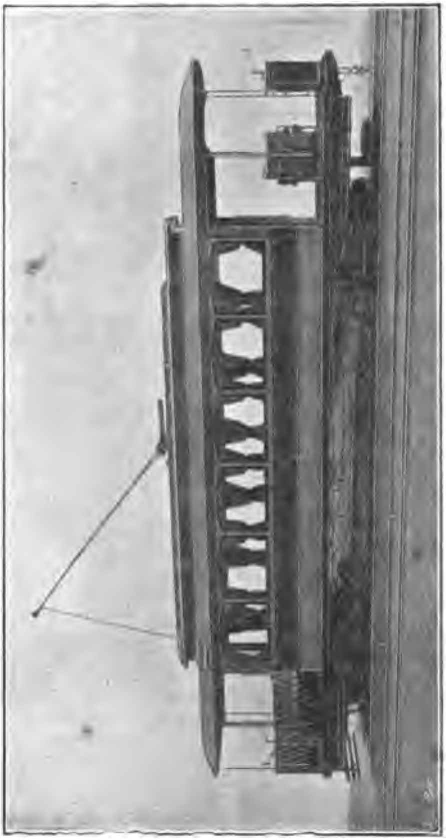
SINGLE TRUCK CAR.

double-deck form is most commonly used, and may be supported either on a single four-wheeled truck or on two separate bogie trucks.

An example of a single-truck double-deck car is given in Fig. 12.

Single-deck cars, of both open and closed types, are in use on some lines, and are carried on single or double trucks, according to their length.

Fig. 13.



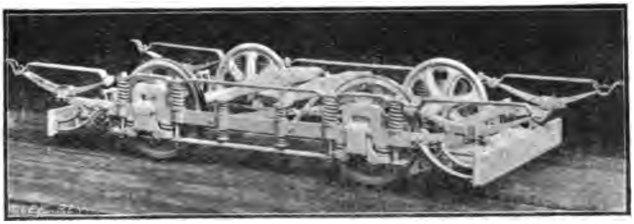
Double Truck Car.

A double-truck single-deck car, with closed and open seats, is shown in Fig. 13.

The body of an electric car is supported on the under truck by suitable springs, and simply serves to carry the motorman and passengers, all the propelling machinery being located in the truck below.

Single Trucks.—A "single" truck, of which a typical example is shown in Fig. 14, is usually equipped with a

FIG. 14.

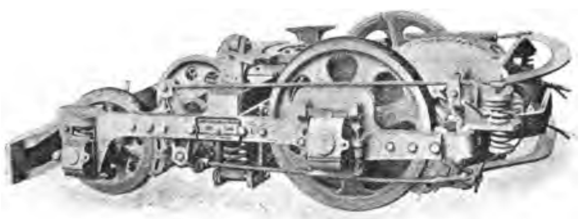


BRILL SINGLE TRUCK.

motor on each axle, the motor being supported by the axle at one side and a strong cross beam at the other. The cross beam is carried on springs on the side frame of the truck, and thus a flexible support is provided to the motors. The motor shafts are furnished with pinion wheels, which gear into large toothed wheels keyed to the car axles, and the power is transmitted in this way to the car wheels.

Maximum Traction Trucks.—A common type of double truck is given in Fig. 15, and is arranged to carry a single motor.

FIG. 15.



BRUSH MAX. TRACTION TRUCK.

The motor drives the large wheels of the truck, and most of the weight of the car is carried on these wheels, to avoid slipping when starting.

The small wheels only carry sufficient load to keep them on the rails, and serve to support one end of the truck.

This form of truck is called the maximum-traction truck.

Ordinary Double Trucks.—Another form of double truck is shown in Fig. 16, and is provided with equal-sized wheels.

This type of truck is employed when **four** motors are fitted to the car, one motor being carried on each axle, which it drives by the usual gearing.

Car Motors.—The motors used on electric cars are

Fig. 16.

Brill Double Truck.

exposed to very severe conditions of service, and must be completely enclosed and protected from all dirt and water.

Fig. 17 shows a car motor, and it will be noticed that it is practically iron-clad in construction, and is arranged to divide into an upper and a lower half, so that the armature and magnet coils can be examined or removed for repairs.

The supply cables are taken in through insulating bushes at the sides, and an inspection cover is provided at the top to allow of the brushes and commutator being examined when necessary.

The armature shaft projects at one end and carries the small driving pinion.

The shaft runs in suitable bearings arranged at the ends of the motor case, and large oil-wells are fitted to keep it well lubricated when running.

The pinion gears into a large toothed wheel on the car axle, and both are protected from mud and grit by a cast-iron gear-case.

FIG. 17.

CAR MOTOR (CLOSED).

FIG. 18.

CAR MOTOR (OPEN).

A motor with its case divided and the armature in position is shown in Fig. 18.

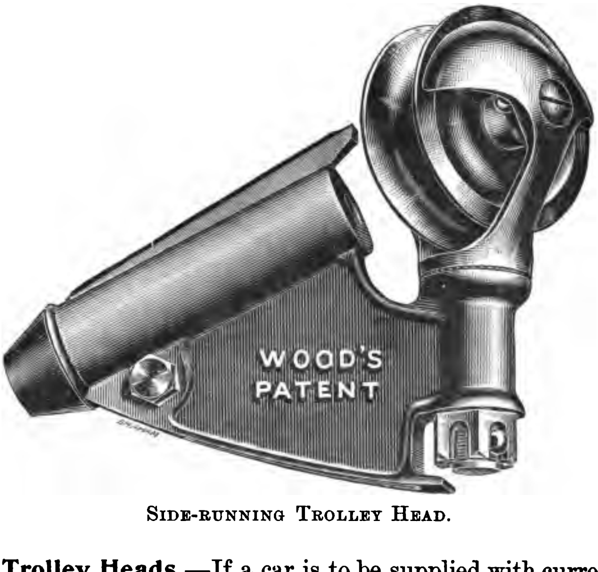
The brush-holders are fixed in the upper half of the case

Fig. 19.

Centre-running Trolley Head.

immediately under the inspection lid, and are easily accessible from the inside of the car after lifting the traps in the floor.

Fig. 20.



Side-running Trolley Head.

Trolley Heads.—If a car is to be supplied with current from overhead wires it is necessary, of course, to provide it with a suitable pole and " trolley " wheel.

If the overhead conductor is suspended directly in line

with the centre of the track a "centre-running" trolley, of the type shown in Fig. 19, is fixed at the end of the pole.

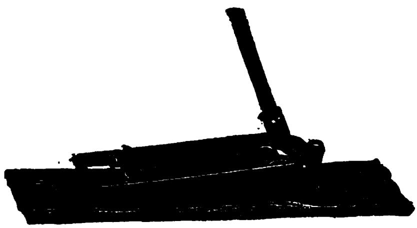
Where the conductors are suspended at the side of the track the trolley head must be capable of swivelling in order to follow the path taken by the wire.

A "side-running" trolley is shown in Fig. 20.

Collecting Ploughs and Skates.—If a car is to be supplied with power from conductors fixed in a conduit it is furnished with a collecting plough as described in Chapter II, and when the vehicle has to run on a "surface-contact" line a collecting skate to make contact with metal studs on the road is fixed on the under truck.

Single-Deck and Double-Deck Standards.—On

FIG. 21.



TROLLEY FOR SINGLE-DECK CARS.

single-deck cars the trolley pole is usually fixed directly on the roof, and by means of suitable springs is pressed upwards against the overhead conductor.

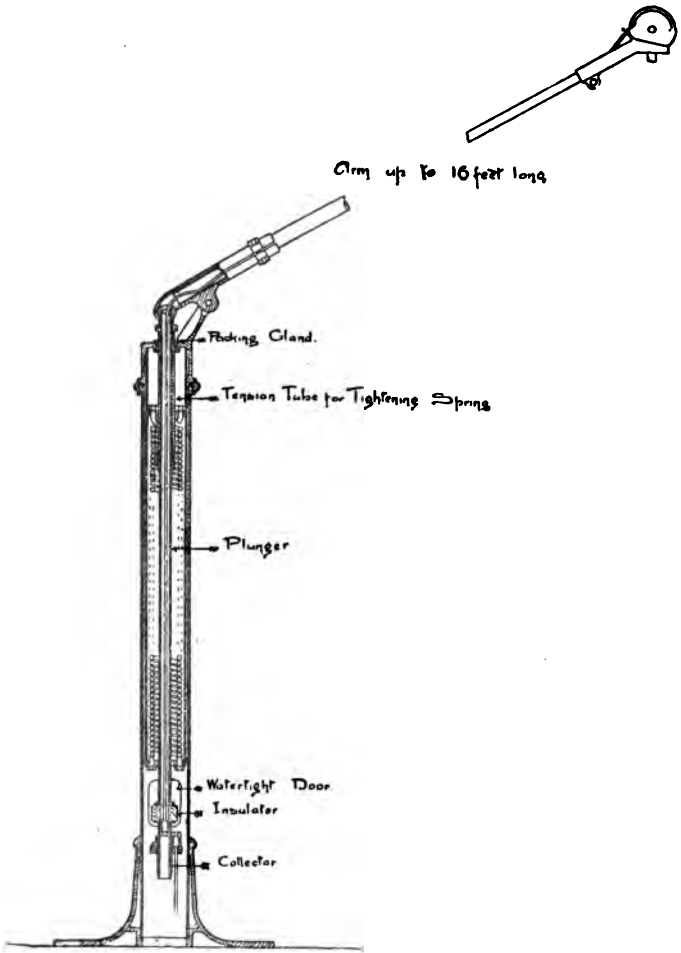
A form of trolley pole suitable for single deck cars is given in Fig. 21; the current collected by the wheel at the end, travels down the metal pole, and by a cable attached to the bottom of it, down to the main switches on the car.

In the case of double-deck cars, where passengers are carried on the top, it is impossible to bring the current down the pole itself on account of the risk of shock to passengers.

A trolley pole and standard for this type of car is shown in Fig. 22, where it will be noticed that the current is brought down from the trolley head to the car by an insulated cable, which passes down through the interior of the pole and supporting standard.

The trolley head is insulated from the pole by a rubber

Fig. 22.



Trolley for Double-deck Cars.

or mica sleeve, which prevents current from reaching the metal pole and standard.

In the type illustrated the pole is pressed upwards by a tension spring fitted inside the standard, but on some makes the springs are mounted on the outside.

The cable from the trolley head usually terminates at a socket at the bottom of the pole, which is free to swivel, so that the pole may be turned round and round in either direction without danger of twisting or breaking the cable.

In some cases the trolley standard is provided with a stop to prevent the pole from making more than one turn round, and the cable from the trolley head passes down through the standard to the car without the intervention of a swivelling plug or socket.

"Leaks" on Trolley Standards.—Although great care is exercised in insulating the trolley head from the pole, and in providing a well-covered cable for the current to pass down, yet it will be understood that through exposure to the weather or through wear and tear a leak may occur and the standard become charged, to the obvious danger of passengers on top.

Safeguards.—To guard against this danger the standard must be connected to the car truck by a stout cable so that any leakage current may be taken direct to the rails, or a signalling device must be fitted to warn the men in charge of the car when the standard becomes charged, so that they may remove the passengers from the upper deck and run the car to the depôt for repairs.

The first noted arrangement is followed on some tramway systems, and when a leak occurs at the trolley head or on the cable the pole is taken off the wire and the car towed to the depôt.

Another plan is to connect the standard to the rails through two incandescent lamps, which may be coloured red and fixed at the car platforms. When the standard becomes charged by leakage current the lamps glow brightly, thus attracting attention to the mishap.

Other devices are in use which cause a bell to ring or a signal arm to be brought prominently into view, so that steps may be taken to prevent any person from coming into contact with the "live" trolley standard.

Path of Current through Car.—In order to understand fully how the current passes through a car and

arrives at the motors the diagram, Fig. 23, should be examined.

It will be seen that the current from the trolley head is led first to an **automatic switch** at one end of the car and afterwards to another **main switch** at the rear platform.

It then passes through a **safety fuse-block** and a **choking coil** before reaching the **controllers.**

When the controller handle is turned the current passes down to the **rheostat** and then to the car **motors.**

FIG. 23.

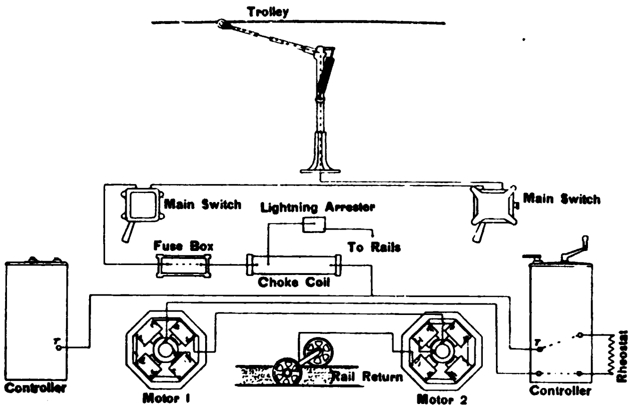


DIAGRAM OF CAR WIRING.

After passing through the motors the current reaches the track rails, and thus goes back to the generating station.

The diagram given follows the usual practice, but the reader must understand that it does not represent the only method in use.

For instance, on some cars the fuse-block is omitted, or the choke-coil may be introduced into the path of the current before the first main switch is reached.

Again, a car may be fitted with **two** automatic switches and the current passed through both in "series;" or these may be connected in "parallel," in which case only one switch is used when the car is running, the one at the rear platform being left at the "off" position.

On cars running on conduit systems, the current, after passing through the motors, does not return to the power station by way of the rails, but goes back *viâ* the **negative** conductor in the conduit.

Main Switches.—The main switches which are generally fixed on the canopy over the motorman are for turning on and off the current, and may be automatic or non-automatic in action.

The **automatic** type of switches, of which examples are given in Figs. 24 and 25, are constructed so that they

FIG. 24.

WESTINGHOUSE AUTOMATIC CAR SWITCH.

spring to the "off" position if an excessive flow of current passes through them.

They serve to protect the motors from dangerous overloads, and are usually adjusted so that it requires a considerable rush of current to trip them "off," such as would occur, for example, if the car was started too quickly, or if a leak occurred in a motor.

Action of "Automatic" Switches.—Many different forms of automatic switches are in use, but they all work on the same general principle, the current passing through the switch being employed to excite a magnet, and, at a certain strength, to knock the switch blade quickly to the "off" position.

Canopy Switch.—A main switch of the **non-auto-**

matic type is shown in Fig. 26, and consists of a pivoted blade, which opens or closes a gap between two contact pieces, according to the position the operating handle is placed in.

When switching off current with this switch the handle should be moved quickly to the "off" position to prevent the current from "arcing," and destroying the contacts.

Fig. 25.

Thomson-Houston Automatic Car Switch.

***Safety* Fuse-blocks.**—It is usual to fit a **fuse-block** on the car, and this device is employed to prevent an abnormal rush of current to the motors or a continuous overload being put on them.

Different forms of fuse-blocks are in use, all of which operate on the same principle.

The whole of the current used by the motors is passed through a short length of wire of a suitable size to carry the current required to propel the car. If the current

exceeds this safe amount, the fuse-wire melts, thus breaking the circuit and stopping the supply of current until the wire has been renewed.

A simple form of fuse-block is shown in Fig. 27, in which the copper fuse-wire is laid into V-shaped brass blocks,

FIG. 26.

BRUSH CO.'S CANOPY SWITCH.

and on closing the box contact is established with the main cables entering and leaving the apparatus, thus providing a complete circuit for the current to pass through.

Another form of fuse-block is shown in Fig. 28. In this type the fuse-wire is contained in a paper tube, which fits into spring clips in the box. When the fuse in the tube "blows" a thin wire on the outside also melts, and serves to indicate the fact. Several spare fuse-tubes are carried on the car for replacement when necessary.

Choking or Kicking Coils.—To prevent lightning from reaching the motors and causing damage a "choking coil" is introduced into the path of the main current, and may

FIG. 27.

WESTINGHOUSE FUSE-BLOCK.

FIG. 28.

NO-ARK ENCLOSED FUSE-BLOCK.

consist of a number of turns of insulated cable wound on a bobbin.

This coil offers little or no resistance to the flow of the ordinary current from the trolley-wire, but it presents a

great obstacle to the passage of lightning, which it diverts to the **arrester,** and thence to the earth by way of the car wheels.

Lightning Arresters.—The Garton-Daniels lightning

FIG. 29.

GARTON-DANIELS' LIGHTNING ARRESTER.

arrester is shown in Fig. 29, and consists of two carbon rods, the points of which are separated from each other by a small air gap. The upper carbon rod can be drawn upwards by a magnet coil, and the gap between the carbons thus lengthened.

The ends of the magnet coil are connected to the bottom and middle terminals of a graphite rod, which serves as a resistance, and is mounted close to the carbons and coil in a suitable box.

When lightning enters the arrester by the line terminal it passes up through the graphite rod, and thence by a flexible wire to the upper carbon rod, and sparks across the small air gap to the lower carbon rod, which is connected to earth (*i. e.* the car wheels).

As the ordinary power current will try to follow the lightning to earth, once an "arc" has been established between the carbon rods, it is necessary to pull the carbons apart and break the circuit. This is done automatically by a portion of the power current passing through the magnet coil, and causing the upper carbon to fly quickly upwards and widen the gap between the two rods.

B. T. H. Arrester.—The Thomson-Houston lightning arrester is somewhat similar to the one just described, except that in it the carbon rods are held permanently fixed at a short distance from each other, and if the power current jumps across the gap after the lightning, it is blown out by the action of a strong electro-magnet which destroys the arc.

Westinghouse Arrester.—In the Westinghouse arrester a block of hard wood is provided with charred grooves across which the lightning can travel to earth without trouble, but the comparatively low pressure trolley-current is unable to follow, owing to the high resistance offered to its passage by the carbonised channels on the wood block.

The wood block and the necessary terminals are enclosed in a small iron case for protection.

Controllers.—After the power current has passed through the main switches, and the safety devices which prevent any excessive flow of current or lightning from reaching the motors, it is taken to the controllers.

The controllers are mounted on the platforms, and are employed to regulate the speed of the car motors and change their direction of rotation.

In Chapter IV several types of car controllers are illustrated and described.

Car Rheostats.—In connection with the controller it is necessary to provide a resistance coil or **rheostat** through which the current is passed, to reduce its pressure before reaching the motors.

In some forms of rheostat the current is passed through a thin metal tape wound in the form of a roll, each layer of tape being insulated from its neighbours by asbestos or

mica, and a number of complete rolls are mounted on a suitable frame and are connected in series with each other. Fig. 30 is a complete resistance "barrel" of the class mentioned; usually two or more of these barrels are required

FIG. 30.

BRUSH CO.'S CAR RHEOSTAT.

on a car, and are mounted under the platforms or in ventilated compartments under the car seats.

Terminals are arranged at each section of the rheostat, to which the cables from the controller may be connected.

As the rheostat becomes heated when current is passed through its coils, it must be constructed of fire-proof

materials, and must not be allowed to come against the woodwork of the car or any material of an inflammable nature.

In some makes of rheostat the resistance material instead of being coiled is built up of zig-zag strips, and each strip connected in series with the next, the whole being mounted on and insulated from a suitable supporting frame.

FIG. 31.

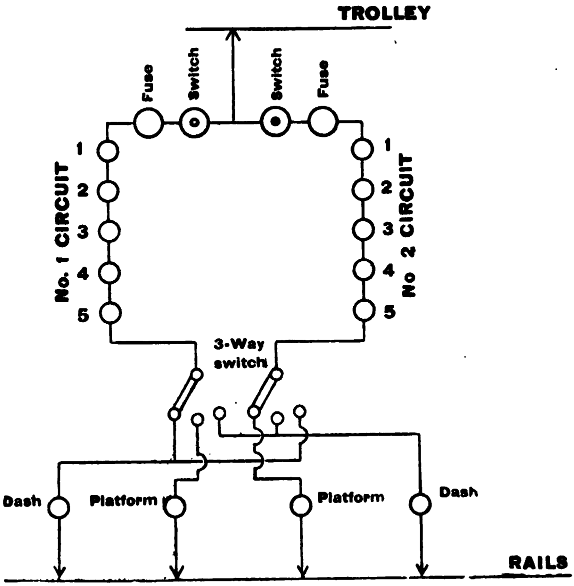


DIAGRAM OF LIGHTING CIRCUITS.

Lighting Circuits.—The incandescent lamps on the car are supplied with current from the trolley wire, a connection being made to the cable from the trolley head immediately after it enters the car.

By tapping off the lamp circuits at this point they are rendered quite independent of the main motor circuit, and the lights may serve to indicate when the current is on or off the line.

It is usual to have two or three separate lamp circuits, so that the failure of one group of lights may not cause

serious inconvenience. Each circuit is made up of five or six lamps connected in series, and is controlled by a small snap switch, and protected by a safety-fuse block.

Dash Lights.—As it is necessary to provide a front dash light whichever way the car may run, the lamp circuits must be arranged for this purpose, and it is also desirable that in the event of one circuit being disabled through the failure of one of the lamps, the dash light may be easily connected to a good circuit and delay be avoided.

Wiring Diagram.—A diagram of connections for car lighting is given in Fig. 31, and gives a good idea of the usual practice, although many different arrangements are in use to suit certain conditions.

Tram-cars are sometimes fitted with a red danger lamp at the rear. This lamp may be arranged to show the route colour on the return journey.

Electric Heaters.—To warm the car small electric heaters may be fitted inside and supplied from the trolley current.

The current passes through coils of thin wire, which become hot, and by means of a switch the amount of heat generated may be varied as required by altering the amount of current going through the heaters.

In this country heaters are not much used, as the climate is fairly temperate, and besides, heaters absorb a considerable amount of current and require a good deal of attention.

Signal Bells.—The signal bells on an electric car are worked by a small **battery,** generally fixed under the car seats.

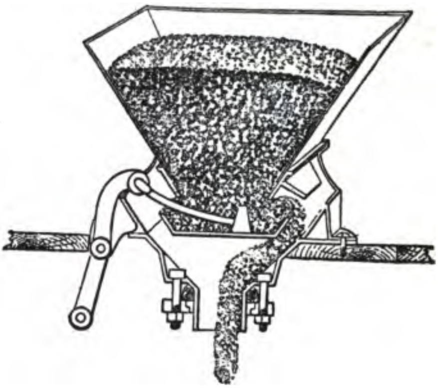
The current from the battery is led by insulated wires to "pushes" at convenient points; on the conductor pressing the centre button of a push, contact is established between two springs inside, and the current is allowed to reach the signal bell at the end of the car and from thence to return to the battery.

If the bell is of the **trembler** type it will continue to ring so long as the button is pressed down. If of the **single-stroke** type the bell will give one sharp ring each time the button is pressed.

Sand Gear.—An important item in the car equipment is the apparatus for dropping dry sand on the track when quick stops are required, or when the rails are greasy and

slippery. Various types of sanding-gear are in use, some of which provide a continuous flow of sand to the rails

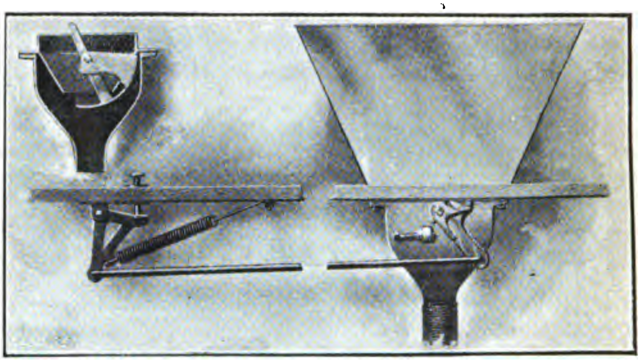
FIG. 32.



INTERMITTENT SAND VALVE.

when in action, while others are constructed to allow only a small quantity to reach the rails at one application.

FIG. 33.



CONTINUOUS SAND VALVE.

In Fig. 32 is shown a sand-gear of the intermittent type,

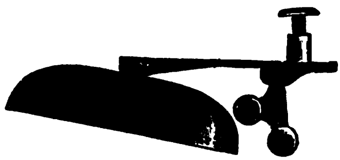
arranged to be operated by a foot-tramp on the car platform.

As will be seen, the sand is contained in a tapered box under the seat, and passes by a pipe down to the rail when the valve is opened by the motorman.

A sand-valve of the constant-flow type is shown in Fig. 33. By slightly opening the valve a small flow of sand is allowed to reach the wheels, and in emergencies the valve can be opened full to allow plenty of sand to fall and assist in stopping the car. Instead of a foot-tramp a small hand-lever is sometimes fitted to operate the sand gear, or a trigger may be fitted to the dash to be moved by the motorman's knee.

On some cars, fitted with air-brakes, arrangements are

FIG. 34.



FOOT GONG.

made to blow the sand under the car wheels for emergency stops.

Dry Sand.—As only small openings are provided in the sand-valve, it is necessary to use only dry riddled sand, and also to prevent paper or sticks from getting into the sand-box when filling it; otherwise delay and trouble may be caused by the valve becoming choked and refusing to act when required.

Foot-gongs.—To warn people of the car's approach a gong is fitted under the platform, and is sounded by means of a foot-tramp.

A car-gong is shown in Fig. 34, where it will be noticed that on pressing down the tramp a heavy clapper is thrown against the rim of the iron gong.

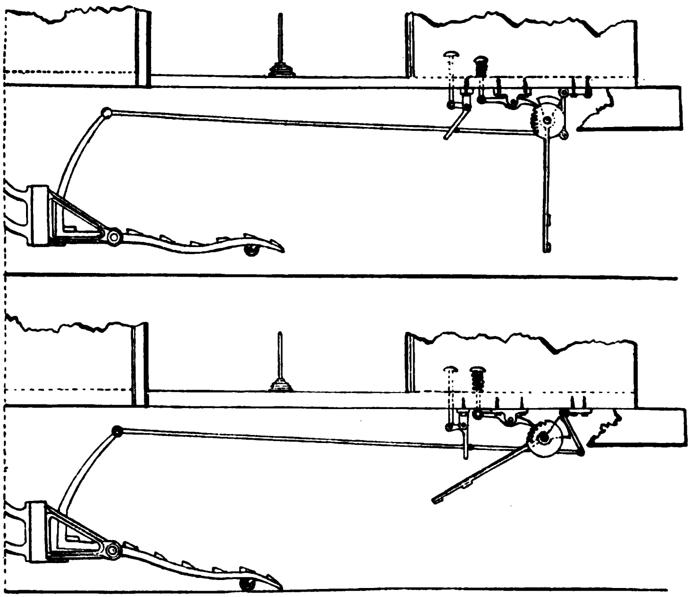
The foot-tramp must not be too short, or it may fail to sound the gong; nor must it be too long, as then it would hold the clapper hard against the gong and prevent it from sounding properly.

Life Guards.—Electric tram-cars are always fitted

with **life guards** to push aside or pick up any person who may fall on the track in front of the car.

Many different forms of guards are in use on the various tramway systems. On some cars strong wire netting is used round the front of the truck, or slanting boards are

Fig. 35.



Trigger Life Guard.

fixed so that they tend to push any obstacle to the side of the line clear of the car wheels.

Another type of guard extensively used is depicted in Fig. 35, and as can be seen, is arranged with a swinging gate or "trigger" in front, against which the obstacle first strikes.

The trigger, when pushed backwards, releases the flat guard behind it, which is pulled down to the surface of the roadway by a strong spring, and thus scoops up any person or obstacle that may have fallen in front.

Destination Indicators.—To indicate the destination of the car a board or screen is generally fitted at each end

Fig. 36.

Destination Indicator.

Fig. 37.

Trolley Catcher.

and bears the name of the place to which the car is proceeding.

Where cars have to run on several different routes, a convenient form of destination indicator is one having the names of the different termini painted on a linen roller or blind, and arranged so that any name may be brought to view by turning a small crank handle.

This form of indicator is shown in Fig. 36, and has fixed inside it a lamp to illuminate the screen at night.

Trolley Catchers.—As considerable damage is often caused by the trolley jumping off the overhead wire when the car is running, several automatic devices have been invented to catch the trolley cord and prevent the pole from flying upward when the wheel jumps off.

A type of trolley catcher for "centre-running" poles is shown in Fig. 37, and consists of a small drum on which the cord from the pole is wound.

The cord is kept taut by means of a spring inside the drum, but if the pole should come off and try to spring up the cord is at once gripped and remains caught until released by the motorman or conductor.

CHAPTER IV.

CONTROLLERS.

Car Controllers.—To regulate the speed of a car, either forward or backward, a **controller** is fitted on each platform, and the current from the line is taken to these after passing through the main switches and the usual overload devices.

The controller is fitted with two removable handles; a small one which is moved forward or back according to the direction in which the car is to run, and a larger one by which the speed of the motors is regulated.

Handles Interlocked.—The large and small handles are "interlocked," and can only be operated in a certain correct fashion.

They can be removed only when the controller is standing at "off" position.

Single Motor Controllers.—When a single motor is fitted to the car, its speed is varied by a simple controller which sends the power through a rheostat to begin with, and then gradually cuts the rheostat out of circuit as the handle is moved round to "full power."

To reverse the car, a small lever is pulled back and operates a switch inside the controller which changes the direction of the current through the motor armature and causes it to run in the opposite direction.

This simple "rheostatic" method of controlling the speed is very wasteful in action, as a large proportion of the power taken from the line is lost in the resistance except when running at "full power."

Series-parallel Controllers.—When two motors are fitted to the car, the rheostatic control is abandoned and the more economical **series-parallel** method is adopted instead.

With this method the controller is arranged to connect

the motors in **series** when low speeds are required, and for high speeds it connects the motors in **parallel.**

When connected in series the current passes first through one motor and then through the other to the rails. When connected in parallel the current divides and passes through each motor separately to the rails.

By connecting the motors in series when starting they each absorb half of the pressure of the supply current, and less current is taken to get the car into motion than if the motors were arranged in parallel.

When the controller handle is brought to the first series "notch" the power is passed through a resistance coil to reduce the pressure before reaching the motors and effect an easy start.

As the controller handle is moved round, the resistance is gradually switched out until, on "full series" notch, it is dispensed with altogether, and the current reaches the motors without obstruction.

"Full Series."—The "full series" notch may therefore be used for any length of time, as no waste is taking place.

On this notch the car runs at about half speed.

To obtain higher speeds the controller handle must be moved round to the **parallel** notches.

On the first parallel position the current is again sent through the resistance, and afterwards passes through the two motors in "parallel," *i. e.* each receives a separate and independent supply of power.

"Full Parallel."—As the controller handle is taken further round, the resistance is cut out by easy stages, and when the full power notch is reached the current is allowed to reach each motor direct, and the car runs up to its maximum speed.

The "full parallel" notch can be used for any length of time without objection, as the rheostat is cut out of action, and all the power is usefully employed in the motors to propel the car.

Advantages of "Series-Parallel" Method.—The advantage of the "series-parallel" method of speed control over the simple rheostatic system is that **two** economical speeds are obtained—"half power" and "full power," and also a smaller rheostat may be employed.

Four-Motor Controllers.—When four motors are fitted on the car they are generally connected in "pairs,"

and the controller is arranged to connect the two "pairs" in series for starting.

For the higher speeds the "pairs" are connected in parallel, and, of course, on "full series" and "full parallel" the rheostat is cut out to prevent unnecessary waste.

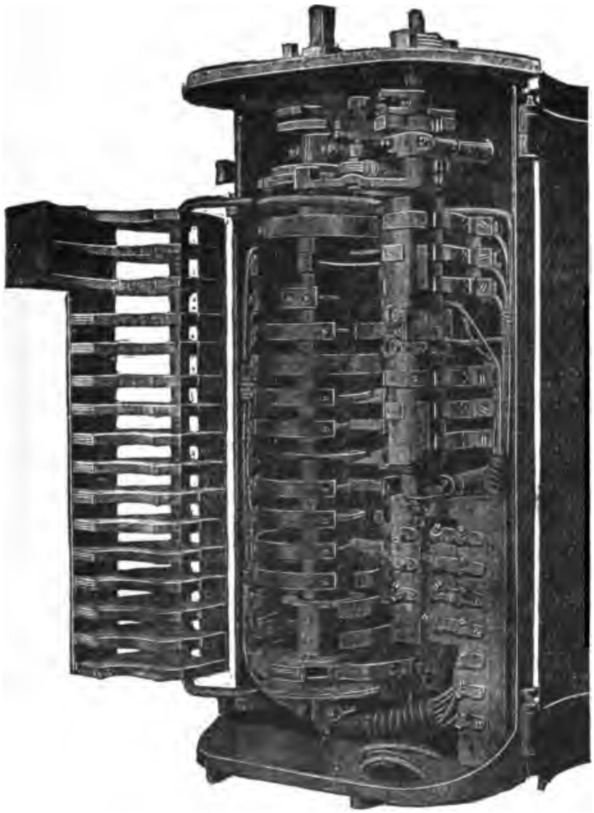


FIG. 38.—WESTINGHOUSE NO. 90 CONTROLLER.

Westinghouse No. 90 Controller.—The Westinghouse No. 90 series-parallel controller is shown in Fig. 38; it is arranged with seven **power** and five **brake** positions.

The large handle turns the main contact drum and regulates the supply of current to the motors, and the same handle regulates the action of the electric "brake."

The small handle is for reversing the direction of running.

Interlocking Gear.—For safety the handles are interlocked so that the small one cannot be removed unless the power handle is at "off," nor can the large handle be moved round unless the small lever is put forward or back.

Main Drum.—When the power drum is turned round it makes contact with several **wipers** or **fingers** arranged at the side, and thus establishes the connections necessary for the different speeds.

Reverse Drums.—By means of the mechanical devices under the top cover the two small drums at the side are turned round when the main drum is turned, and these make connection with side fingers, so that the current passes through the car motors in a certain direction.

The direction in which these small drums revolve, and therefore the direction in which the car travels, depends on the position in which the small handle of the controller is placed.

Notch Wheel.—To hold the main drum firmly at the "off" position or at any of the intermediate points, a "notch" or "star" wheel is fitted on the main shaft, and a pivoted lever, having a small roller at one end, is pressed firmly against the notches by a powerful spring, and serves to keep the power handle at the various positions.

Terminal Board.—The cables from the motors and rheostat, and the supply cable from the line, are brought into the controller and attached to brass "terminals" at the bottom of the case. From these terminals connections are taken to the spring contact fingers at the side of the large and small drums.

Arc Shield.—To prevent flashing between adjacent fingers as the main drum is turned, a hinged **arc-shield** is fitted, having fireproof divisions, which lie between the drum segments.

Brake Notches.—When the power handle is turned to the "brake" notches the controller connects the motors so that they act as generators while the car is running, the current produced being absorbed in the rheostat.

Five brake notches are provided, so that the amount of

current taken from the motors may be regulated according to the braking effect required.

Motor Cut-outs.—In the event of one of the motors

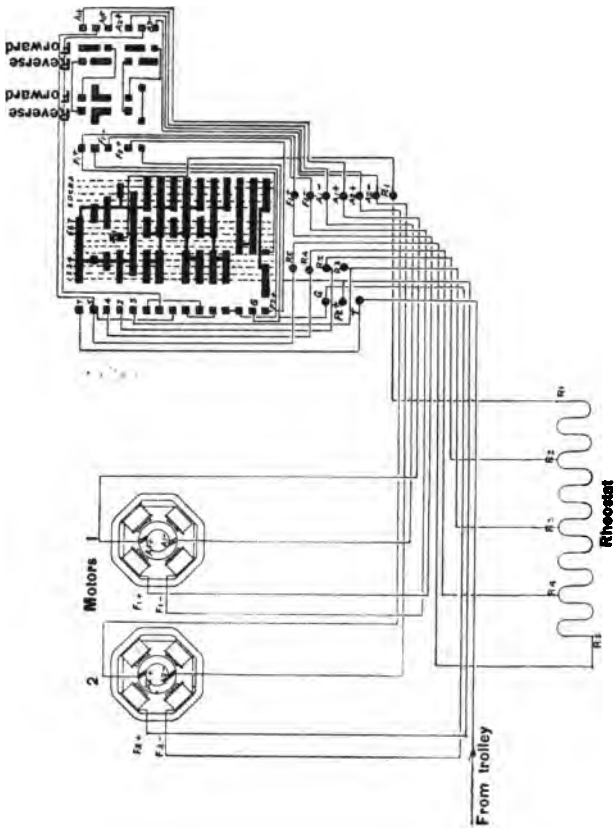


FIG. 39.—DIAGRAM OF WESTINGHOUSE NO. 90 CONTROLLER.

becoming defective it is necessary to disconnect it from circuit, and to arrange the connections so that the remaining good motor may be available to drive the car.

To do this, one of the small drums must be turned round to the right by pulling out the small brass knob attached to it.

When a motor "cut-out" has been moved over, a small catch is pushed out and prevents the power drum from turning past "full-series" notch, and the car runs at its top speed on this point.

Diagram of Connections.—The complete connections for a No. 90 controller are given in Fig. 39.

How to Read it.—The controller drums are shown as if they were flattened out, and the positions which the drums take when on the various notches are indicated by dotted lines, having the notch numbers marked at the top.

The correct way to work from the diagram is to imagine all the fingers to be moved over to the dotted line under consideration, and then trace the path of the current along the lines and segments.

It will be noted that the main drum is in six parts, each insulated from its neighbour and from the shaft.

When considering the connections made on the parallel notches it should be remembered that the current has to divide to both motors, and afterwards get to the rails (*i. e.* ground).

"Trolley" Finger.—The "T" finger is not in contact on any of the brake positions, as no current is then required from the line.

Finger R1 makes contact on 1st brake notch.

"Equaliser" Fingers.—The two bottom fingers are both in contact on all brake points, but only one of these fingers should make contact when the controller is on the power positions.

The brake points are marked A, B, C, D, and E.

Connections Made.—The following are the connections made by this controller on the different notches:

1st power notch.	Motors in series.	Rheostat in action,	R 2.
2nd " "	" "	" "	R 3.
3rd " "	" "	" "	R 4.
*4th " "	" "	" cut out,	R 5.
5th " "	Motors in parallel.	" in action,	R 3.
6th " "	" "	" "	R 4.
*7th " "	" "	" cut out,	R 5.
1st brake notch.	Motors in parallel.	Rheostat in action,	R 1.
2nd " "	" "	" "	R 2.
3rd " "	" "	" "	R 3.
4th " "	" "	" "	R 4.
5th " "	" "	" cut out,	R 5.

* Running points.

Westinghouse No. 210 Controller.—The Westinghouse No. 210 controller is shown in Fig. 40, and is arranged with nine power and seven brake notches.

Fig. 40.

Westinghouse No. 210 Controller (open).

Magnetic Blow-out.—To reduce sparking at the drum and contact fingers a **blow-out magnet** is fitted, and is energised by the main current passing through the large coil at the side.

The hinged pole-piece and arc shield are held in position by a catch at the bottom, and can be swung clear when necessary.

The exciting coil of the blow-out magnet is cut out of action on the "full series" and "full parallel" positions to avoid waste of power.

Reverse Drums.—The two small reversing drums are turned round by means of a slotted lever worked from the main spindle.

Motor Cut-outs.—To disconnect a defective motor from service it is necessary to pull forward a small brass

FIG. 41.

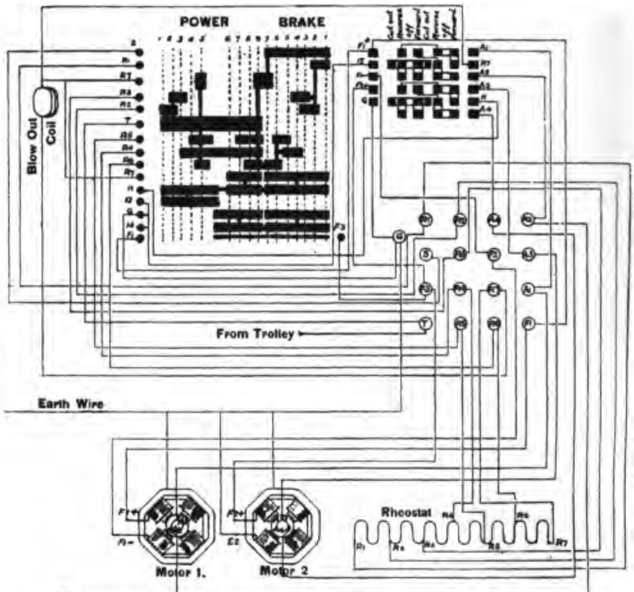


DIAGRAM OF WESTINGHOUSE NO. 210 CONTROLLER.

knob and turn one of the small drums to the right, using the small reversing lever for this purpose.

As usual, a catch is provided to prevent the power handle passing full series when running with one motor.

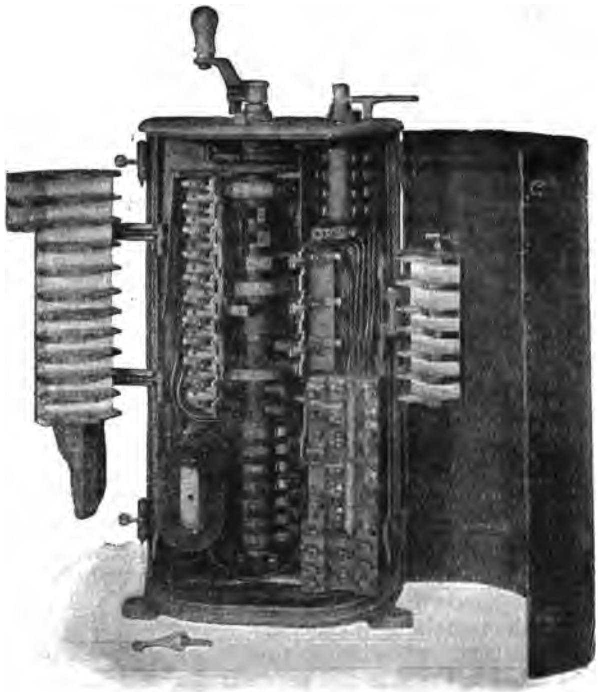
Terminal Board.—The cables from the line, motors, and rheostat enter at the bottom, and are attached to brass terminals which are connected to the various "fingers" in the controller.

Connection Diagram.—The complete connections for a controller of this type are given in Fig. 41.

It will be noted that the two bottom fingers are in contact on all brake positions, but must not **both** touch when drum is on power points.

The top finger is in contact on all brake notches, and

FIG. 42.



THOMSON-HOUSTON B-18 CONTROLLER (OPEN).

serves to take the current generated by the motors to "ground," or to the coils of the magnetic brake if such appliance is fitted to the car.

Westinghouse No. 412 Controller—The Westinghouse No. 412 controller is similar to the No. 210, but is arranged to control "four-motor" equipments instead of two only.

Thomson-Houston Controllers.—The Thomson-

Houston Co. manufacture several types of series-parallel controllers for tramway work.

Some of these are arranged for electric braking, and are termed "Type B."

Others are arranged with only an "emergency stop" position, and are called "Type K."

B-18 Controller.—A B-18 controller is shown in Fig. 42, and is capable of controlling two 30-H.P. motors.

Eight **power** and six **brake** notches are provided, and as usual with T-H controllers a "blow-out" magnet is fitted to reduce arcing at the contacts.

Blow-out.—The controller is depicted with the hinged shields pulled forward, and the magnet coil can be noticed at the lower left-hand corner.

Interlocking Gear.—An interlocking catch is fitted to prevent wrong manipulation of the controller, and a notched wheel at the top of the main drum with roller pawl serves to hold the controller handle steady at the different positions.

Main Drum.—The main drum makes contact when turned with spring "fingers" arranged at both sides, and at the bottom of the main spindle a smaller drum is fitted and makes contact with side fingers also.

Reverse Drum.—The reversing handle serves to turn the small contact drum directly under the top cover, and changes the armature connections to allow of the car running backward when necessary.

Motor Cut-outs.—To allow of a defective motor being switched out of circuit, two small switches are fitted at the right-hand side; by moving one of these switches over to the left the corresponding motor is cut out, and the car runs on the remaining good one.

When a "cut-out switch" is pulled over, a brass rocking bar is tilted to the side and prevents the controller handle from being moved past half power.

Terminals.—The supply cable (T) is attached to a terminal on the "blow-out" coil, and the other cables are connected to the terminals at the other side, and are all plainly lettered for identification.

Ground Screw.—When the car is running on a single trolley system the outer case of the controller is connected by a brass screw to the ground terminal (G) to prevent the case from becoming "live" through leakage current.

B-18 Diagram.—The connections for a B-18 controller are given in Fig. 43.

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Fig.

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Fingers R1 and R3 are used on the 1st and 3rd brake notches, and finger 25 is in contact only on the series points.

Finger B makes contact on all brake notches, and may be connected to "ground" for rheostatic braking, or to the magnet coils if magnetic brakes are used.

FIG. 45.

THOMSON-HOUSTON B-13 CONTROLLER.

B-3 Controller.—The B-3 controller is similar to the B-18, but is arranged for use with the Thomson-Houston magnetic disc brakes, and on the 1st power position it permits trolley current to pass through the brake coils to make them slack off.

B-6 Controller.—The B-6 controller is arranged for controlling cars fitted with four motors, and in general design is similar to the B-18 except for some slight differences at the terminal board and reverse drum.

As the motors are connected in "pairs," moving over one of the cut-out switches disconnects two motors and leaves the other two to propel the car.

The connections made by this controller on the power and brake notches are given in Fig. 44.

B-13 Controller.—The B-13 controller is arranged with nine power and seven brake points, and is suitable for use with magnetic disc brakes.

The main drum is of the usual construction; a smaller one is fitted at the side and is turned into contact when the main spindle is brought round.

The reverse drum is worked direct by the small handle of the controller as usual, and is "interlocked" with the power drum.

The terminal board is fixed at the left of the case, and immediately above are fitted the motor cut-out switches.

In Fig. 45 a B-13 controller is shown open.

Type "K" Controllers.—The Thomson-Houston "Type K" controllers are not arranged for electric braking, but provision is made for an emergency stop by short circuiting the car motors.

This is effected by throwing the reversing handle past the usual positions, and a small catch locks it in either of the "emergency" points until intentionally released after the car stops.

K-10 Controller.—A K-10 controller is shown in Fig. 46, where it will be seen that the usual construction is followed, except that the terminal board and motor cut-outs are somewhat differently placed.

Nine power and seven brake notches are provided, and a magnetic blow-out is fitted to reduce arcing at the fingers and drum contacts.

K-9 and K-11 Controllers.—The K-9 and K-11 controllers are similar to the K-10, except that the K-9 is arranged for double trolley or conduit lines, and the K-11 is for two 50-H.P. motors.

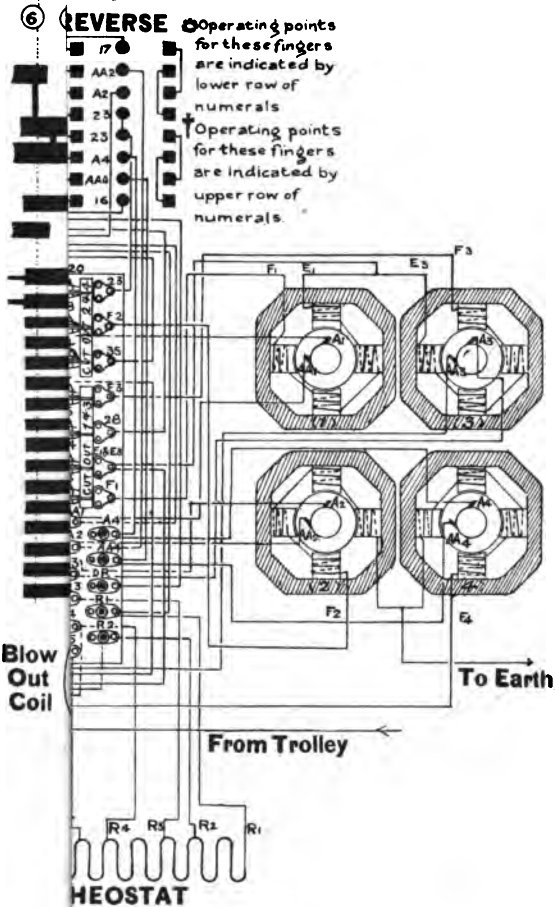
K-12 Controller.—The K-12 controller is arranged for four-motor equipments, and in general design is similar to the K-11 class.

K-2 and K-1 Controllers.—The K-2 and K-1 controllers have nine power notches, and have **four** points where the rheostat is cut out of action.

On the 4th notch the motors are in series without resistance, and on the 5th the current through the field-

B sistance Points ◯ indicates Brake Points

6 nning Points 5.6.7.8. are Transition Points



magnet coils is reduced by a "shunt," and the car runs a little faster.

On the 8th notch the motors are in parallel with all

FIG. 46.

THOMSON-HOUSTON K-10 CONTROLLER.

resistance cut out, and on the 9th notch the field-magnets are again "shunted," and the speed increased thereby.

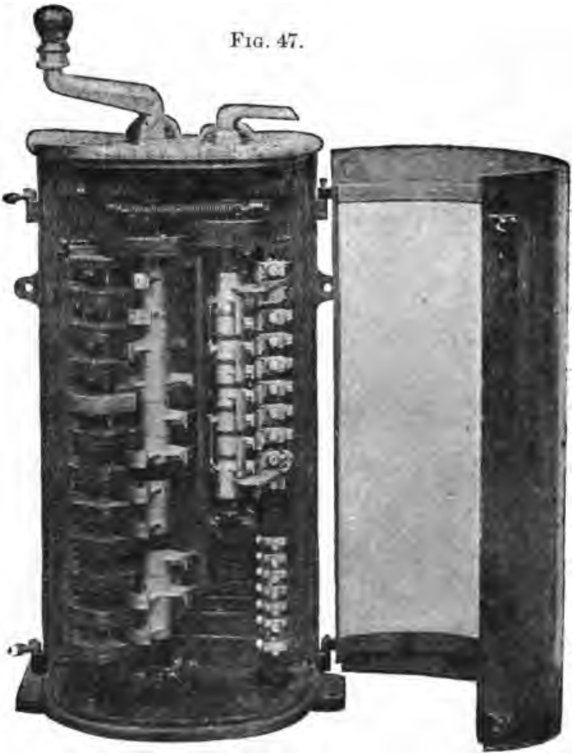
The 5th and 9th notches are suitable for fast running on the level, but should not be employed on heavy grades or where a strong pull is required.

Brush Co.'s Controllers.—The Brush Co. make

several types of car controllers arranged for "series-parallel" working.

H-2 Type.—The H-2 is shown in Fig. 47; it has

Fig. 47.



Brush Co.'s H-2 Controller (open).

seven power notches (four series and three parallel), and the reverse handle may be moved to an "emergency stop" position, when the motors are short circuited, and act as a powerful brake.

H-3 and H-4 Types.—The Brush H-3 and H-4 controllers are similar to the H-2 in general construction, except that the H-3 is arranged to "shunt" the field coils of the motors on the last notch for fast running, and the H-4 is for four-motor equipments.

H. G.-2 Controller.—The H. G.-2 controller is like the H-2 on the power side, but the reverse lever has one position for connecting the motors so that they act as generators and feed back current into the line when the car is descending long steep grades, thus acting as an economical type of electric brake.

Blow-out "Solenoid."—To reduce arcing at the

FIG. 48.

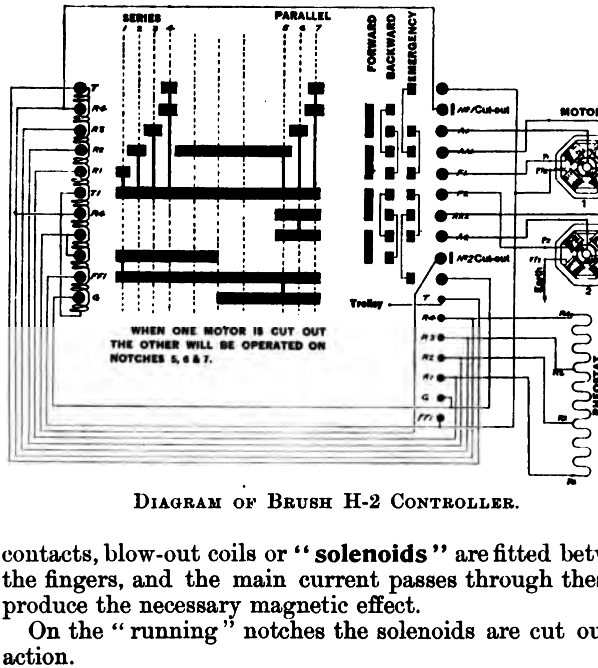


DIAGRAM OF BRUSH H-2 CONTROLLER.

contacts, blow-out coils or "**solenoids**" are fitted between the fingers, and the main current passes through these to produce the necessary magnetic effect.

On the "running" notches the solenoids are cut out of action.

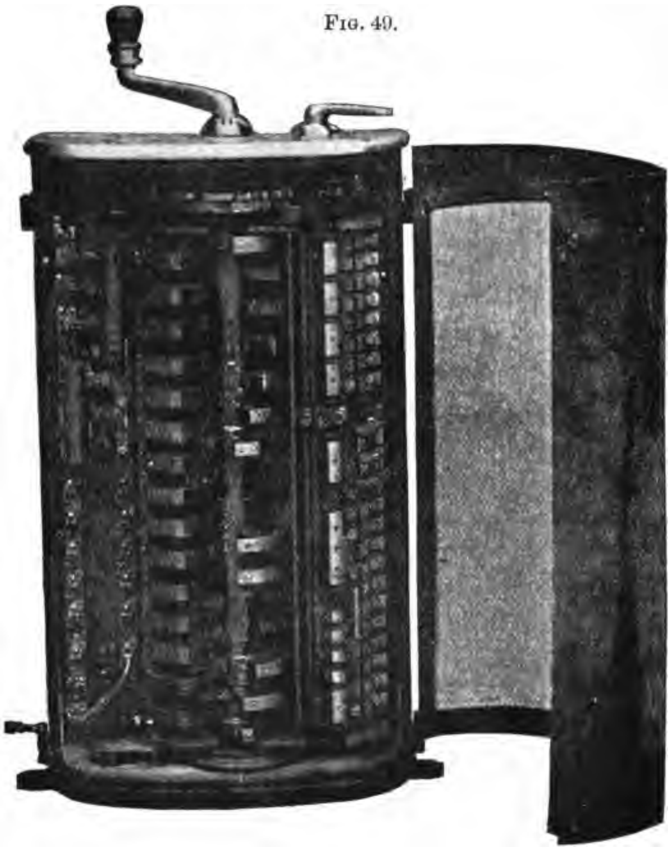
Motor Cut-outs.—To cut out a defective motor it is necessary to pull back one of the fingers at the side of the reverse drum, and the remaining good motor is then operated on the **parallel notches** only.

H-2 Diagram.—A diagram of the connections for an H-2 controller is given in Fig. 48, and is typical of the other forms mentioned.

H. D-2 Controller.—The H. D.-2 controller has nine power and seven brake points, and is illustrated in Fig. 49.

Main and Auxiliary Drums.—In addition to the main drum two smaller drums are fitted at the side; the top one being operated by the reverse handle, and the bottom one

FIG. 40.



BRUSH H. D-2 CONTROLLER (OPEN).

being turned into contact with side fingers according as the main drum is moved to the "power" or "brake" notches.

"**Solenoid.**"—A blow-out solenoid is fitted at the main drum fingers to prevent arcing when switching off power,

and this can be pulled forward when it becomes necessary to clean or examine the contacts.

FIG. 50.

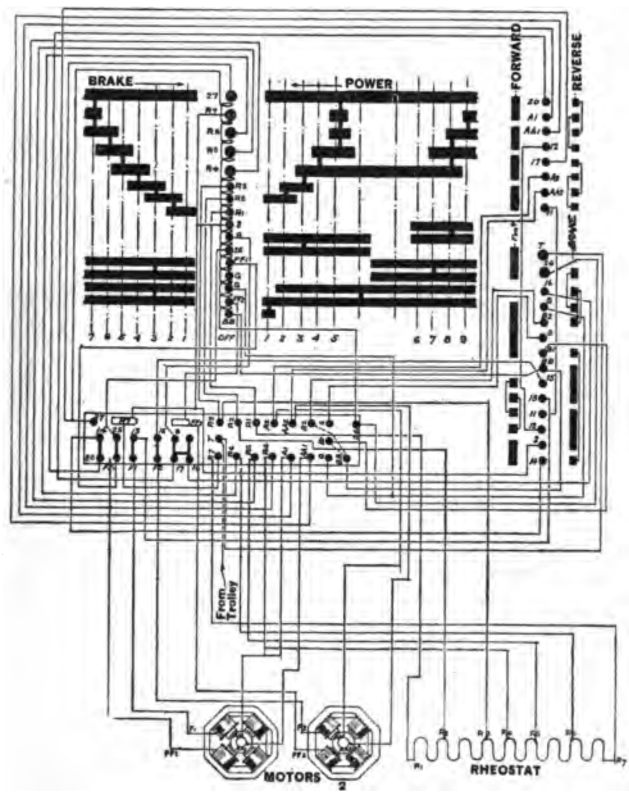


DIAGRAM OF BRUSH H. D-2 CONTROLLER.

Motor Cut-outs.—The motor cut-out switches are mounted over the terminal board at the left-hand side, and a catch is fitted to prevent the power handle passing full series when running with one motor only.

H. D.-2 Diagram.—The connections for an H. D.-2 controller are given in Fig. 50.

Dick-Kerr Controllers.—Messrs. Dick, Kerr and Co. supply several types of series-parallel controllers.

In Fig. 51 one of their D. B.-1, Form C, controllers is shown open.

FIG. 51.

DICK-KERR CONTROLLER.

Seven power and five brake notches are provided.

As usual, the operating handles are interlocked, and can only be removed when the controller is brought to the "off" position. The small handle turns the contact drum

directly underneath and controls the direction in which the car travels.

The large handle serves to turn the main cylinder into contact with the side fingers.

A small contact drum is fitted at the bottom of the large cylinder, and is turned round when the controller is moved to the "power" or "brake" notches.

When the handle is moved to the power notches the small drum at the bottom is turned into contact with side fingers, and allows the trolley current to reach the motors to propel the car.

When the handle is moved to the brake notches the small drum is turned in the contrary direction, and connects the motors, so that they act as generators, and serve to stop the car quickly when found necessary.

Magnetic Blow-out.—To prevent destructive arcing when switching off, a "magnetic shield" is fitted at the side of the main contact drum.

This device consists of coils of insulated wire, through which the main current is passed. Opposite the fingers are fitted copper bobbins, each bobbin being separated from its neighbour by insulating fireproof partitions.

The action of the device is to attract the arcs which occur at the fingers and cylinder contacts to the copper bobbins, and extinguish them before they can cause damage by burning.

The coils in the magnetic shield are cut out of action at full-series and full-parallel, to avoid waste.

Motor Cut-outs.—To cut out a defective motor it is necessary to pull back one of the fingers at the side of the small reverse drum at the top of the controller.

The cut-out fingers are marked No. 1 and No. 2, and have catches provided to hold them off when required. When a motor is cut out the car is operated on the parallel notches only.

In Fig. 52 is given a diagram of connections for a car fitted with Type D. B.-1, Form C, controllers, arranged for use on the trolley system, with rail return.

In conduit systems the current, after passing through the motors, returns to the power station by one of the underground conductors.

Two main switches are fitted on the car, one to disconnect the positive cable from the collecting plough, and the

FIG. 52.

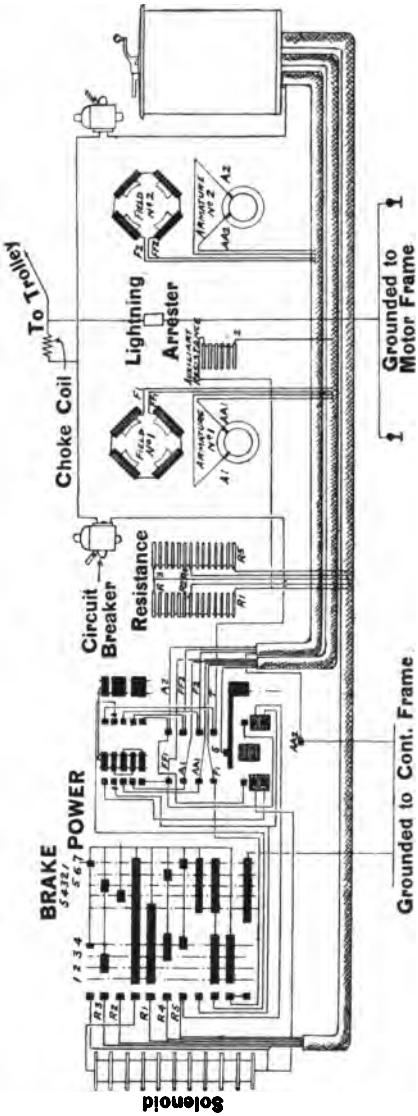
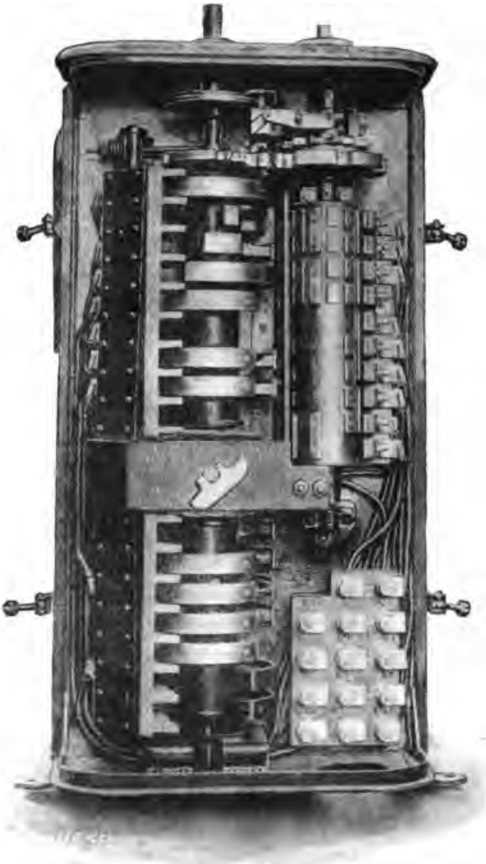


DIAGRAM OF DICK-KERR CONTROLLER.

other to disconnect the negative cable, so that the car may be completely cut off from the line when necessary.

FIG. 53.



WITTING-EBORALL CONTROLLER.

Witting, Eborall and Co.—The controllers supplied by this firm are all built on much the same lines, whether for operating two or four motors. The main point of difference between the controllers for two motors and for

four motors lies in the different connections necessary, and the extra number of positions of the controller cylinder.

For four motors, in the series positions, each pair of motors is connected in parallel, and the two pairs in series.

In Fig. 53 an E. H.-9 controller is shown with outer cover removed.

It will be sufficient to describe the standard controller E. H.-10 for two motors. The necessary connections are made by two movable cylinders, one large and one small.

The small cylinder is arranged to control the direction of rotation of the two motors, or of either of them, while the large cylinder controls the starting, running, and braking.

The two cylinders are connected by an interlocking gear arranged so that it is impossible to reverse when current is on the motors. Further, it is impossible to move the large cylinder unless the small cylinder is in one of its working positions.

Reverse Drum and Cut-outs.—The reversing cylinder has six positions to which it can be moved by hand, and the following connections can be made by means of it, the two motors being denoted by A and B respectively.

1. Motor A and Motor B . . .	Forwards.
2. „ „ . . .	Backwards.
3. Motor A alone	Forwards.
4. „ „	Backwards.
5. Motor B alone	Forwards.
6. „ „	Backwards.

Thus by means of this cylinder either motor can be used alone, and no separate motor cut-outs are required.

Connections made.—The controlling cylinder allows the following connections to be made.

1st power notch.	Motors in series.	Rheostat	in action,	R 2.
2nd „ „	„ „	„	„	R 3.
3rd „ „	„ „	„	„	R 4.
*4th „ „	„ „	„	cut out,	R 5.
5th „ „	Motors in parallel.	„	in action,	R 3.
6th „ „	„ „	„	„	R 4.
*7th „ „	„ „	„	cut out,	R 5.
1st brake notch.	Motors in parallel.	Rheostat	in action,	R 1.
2nd „ „	„ „	„	„	R 2.
3rd „ „	„ „	„	„	R 3.
4th „ „	„ „	„	„	R 4.
5th „ „	„ „	„	cut out,	R 5.

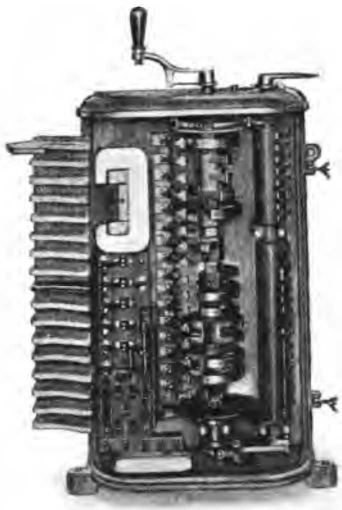
* Running points.

Should either of the motors be cut out by the reversing cylinder, the controlling cylinder makes the above connections with the remaining motor.

When running with one motor alone, the controller cannot be taken past the full-series notch.

Bruce Peebles Controller.—Messrs. Bruce Peebles and Co.'s series-parallel controller is shown open in Fig. 54. Nine power and seven brake notches are provided.

FIG. 54.



BRUCE PEEBLES CONTROLLER.

The main drum when turned moves, by gearing, the small drum at the side, and establishes the proper connections for "running" and "braking."

The small drum at the top serves to reverse the motors, and is interlocked with the main drum.

A magnetic blow-out is fitted to reduce arcing, and two motor cut-out switches are mounted immediately over the terminal board on the right.

Regenerative Control.—Instead of employing series wound motors with a rheostat in the main circuit to

control the flow of current when starting and accelerating it is practicable to use motors having shunt wound field magnets, and to vary the speed of the car by varying the strength of the field magnets.

With shunt wound motors it is possible to use the motors to brake the car electrically and return to the overhead line some of the current thus generated instead of wasting it in the rheostat as is done with the ordinary electric brake and series wound motors.

The usual arrangement for regenerative control is to first excite the field magnets of the car motors to their full strength and then admit the current to the armatures through a small main rheostat. Under these conditions the car runs at its lowest speed.

By altering the strength of the field magnet current the speed of the motor can be increased to the maximum, or varied according to requirements.

An auxiliary rheostat is used to vary the strength of the shunt current.

As the shunt wound motor will try to run at a constant speed up hill or down hill, according to the strength of its field magnets, it will be understood that when it becomes needful to reduce the speed of the car, or descend inclines, it is merely necessary to increase the strength of the shunt current and the motors will automatically retard the car or check its speed down the hill.

The work done in retarding the car is absorbed in driving round the motor armatures, and the motors being driven in this fashion act as generators and feed current back into the line.

Several arrangements of regenerative control apparatus have been devised by engineers, and indications point to a more extended use of this system of car control in the near future.

Raworth's Regenerative Controller.—This controller is shown in Figs. 55 and 56, and is provided with two handles interlocked to prevent wrongful operation.

Fig. 55 shows the "speed" lever, which is permanently attached to the controller, and operates the rheostat inserted in the field magnet circuit of the car motors.

In Fig. 56 the removable "power" lever which operates the rheostat in the armature circuit is shown in the "on" position.

When the controller is at the "off" position the speed

lever is in the forward position and the power lever in the backward.

In these positions the power handle locks the speed lever at its "off" position and prevents anyone operating the controller unless he is in possession of the power handle.

To operate the controller the power lever must be pushed

FIG. 55.

SPEED LEVER.

FIG. 56.

POWER LEVER.

slightly forward to position P.L. 2 (see Fig. 57). By this movement the speed lever is unlocked, and can be brought back to the position of maximum field strength of the motors.

The power handle can then be moved to P.L. 3 so as to allow current to pass through the motor armatures, and start the car slowly on the resistances.

During this movement of the power handle the speed lever is locked, but when the power handle reaches the "on" position P.L. 4 the speed lever can be pushed forward, and by reducing the strength of the field magnets causes the car motors to run faster.

The controller cover has notches which can be marked with numbers indicating the speeds at which the car will travel, and if the lever is allowed to remain at any particular notch the speed will remain practically constant whether running up hill or down.

FIG. 57.

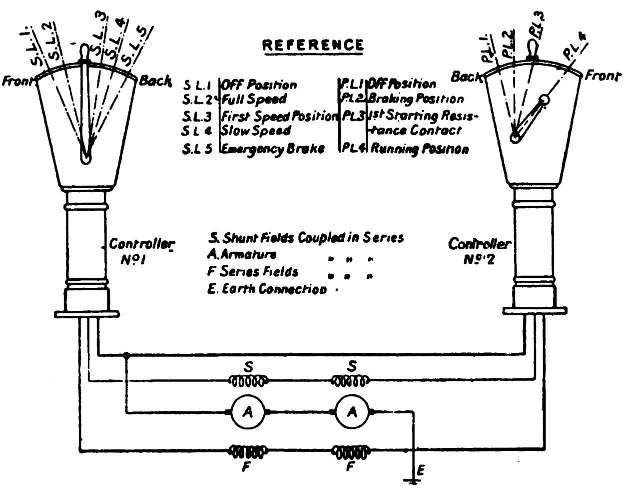


DIAGRAM SHOWING ARRANGEMENT OF ARMATURES AND FIELDS.

To brake the car or control its descent down inclines the speed lever is pulled back notch by notch according to requirements.

To reduce the speed below the minimum given when the speed lever is at full excitation position the armatures are short circuited through resistances on position S.L. 4, and power handle on P.L. 2.

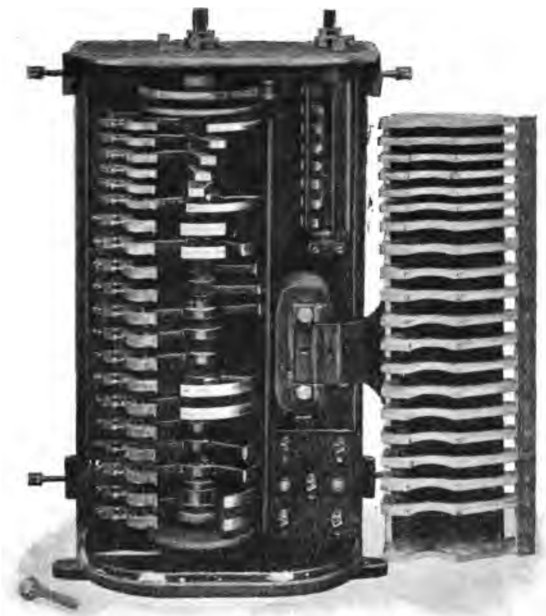
In addition to the shunt winding the motors are furnished with a few series coils, so that in emergencies, such as the trolley leaving the wire and the shunt excitation failing, the series coils can be brought into operation, and

the car pulled up by this means. This emergency brake position is shown at S.L. 5, where the speed lever is pulled back to full extent.

With this controller the car motors are always connected in series.

Another form of controller arranged for regenerative braking has been devised by Raworth's Traction Patents,

FIG. 58.



RAWORTH'S CONTROLLER.

Ltd., and is similar in appearance to the ordinary series parallel controller.

It permits of the car motors being operated in series or in parallel with the attendant economical advantages, and is shown in Fig. 58.

The Johnson Lundell Co.'s system of regenerative control is arranged so that the car motors act as series-wound machines when accelerating and running, and as compound-wound machines when regenerating and braking.

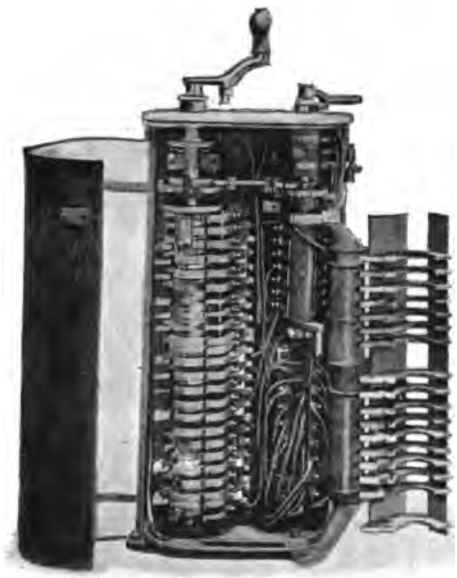
The motors are fitted with double-wound armatures and two commutators, and, when starting the car, all the armature windings are connected in series and the field magnets are excited to full strength.

On the first notch of the controller current is admitted to the armature windings through a small rheostat.

On the remaining nine notches the armature resistance is cut out of action and waste prevented.

The Johnson Lundell controller is shown in Fig. 59, and

Fig. 59.



Platform Controller.

is similar in appearance to an ordinary series parallel car controller.

The car is started by turning the large handle round as usual, but with the great advantage that every notch except the first is a "running" notch, and the speed of the car can be nicely varied to suit traffic conditions.

When it is desired to use the regenerative action of the motors and reduce the speed of the car it is necessary to

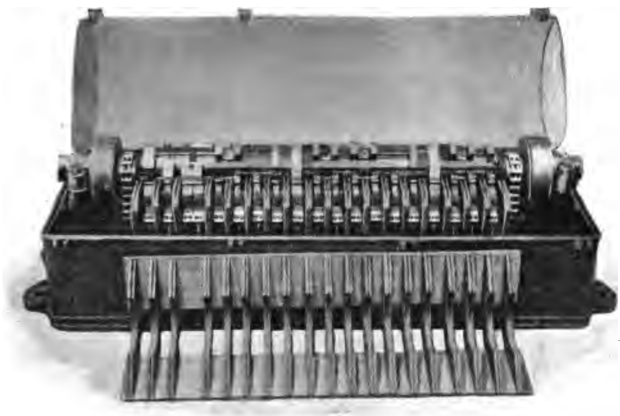
press a small button on the handle, and then move the controller back notch by notch to the speed desired.

Pressing the button on the controller handle operates the "field changer," Fig. 60, and alters the motor field magnet connections from series to compound.

In common with all "electric" brakes, regeneration cannot suffice to hold the car on a grade, and it becomes necessary either to apply the hand brake or employ some automatic brake gear such as is shown in Fig. 61.

This automatic brake gear is controlled electrically by a solenoid connected to the car controller, so that when the

FIG. 60.



FIELD-CHANGER.

controller handle is moved to the first notch the heavy iron core of the solenoid is lifted and the brakes are released from the car wheels. When the controller is moved to the "stop" position the solenoid allows the core to drop, and causes a stout steel cable to tighten up round a drum on the car axle, and thus apply the brake blocks to the wheels.

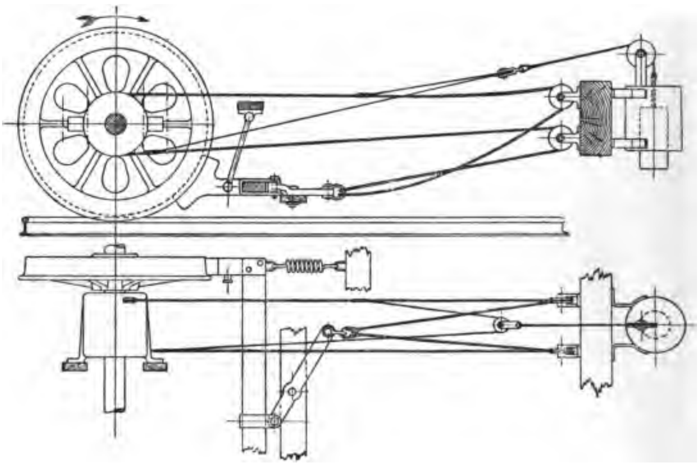
Automatic Acceleration.—A considerable economy in current consumption can be effected by feeding up the controller at such a rate as to make the motors work at their most efficient load, and also reduce the loss in the

rheostats. Several devices have been tried in practice which regulate the movements of the power handle so as to secure to some extent the best results. It is wasteful to turn on the power too quickly, and it is also objectionable to feed up slower than the occasion demands.

The Automotoneer (Fig. 62) is a device which controls the movement of the power handle through the action of an air dash-pot mechanism.

The movement of the controller handle from one notch to another moves a piston which drives the air out of a small dash-pot. The raised position of the piston locks

FIG. 61.



JOHNSON AUTOMATIC BRAKE GEAR.

the handle against further advance until sufficient time has elapsed.

The rate of advance can be regulated by adjusting the size of the air inlet of the dash-pot, and in any case the controller handle cannot be moved more than one notch at a time.

The device does not interfere in any way with the switching off movement.

Durkin Controller Handle.—This power handle is designed to regulate the rate of feeding up the controller, and consists of a special attachment for fixing to the top of existing controllers.

A hinged latch or "dog" is pivoted under the handle in

such a way as to engage in suitably spaced notches and delay the movement of the controller handle for a moment on each position, thus insuring a steady rate of acceleration.

FIG. 62.

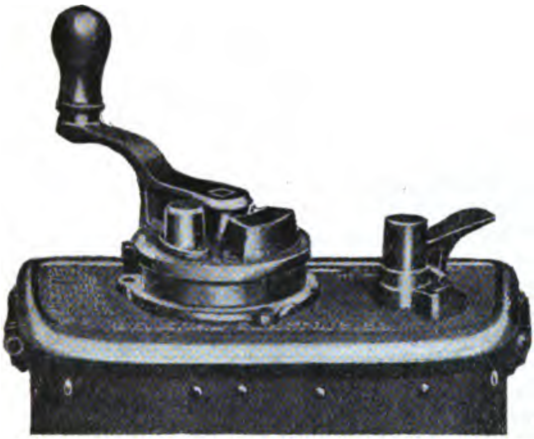
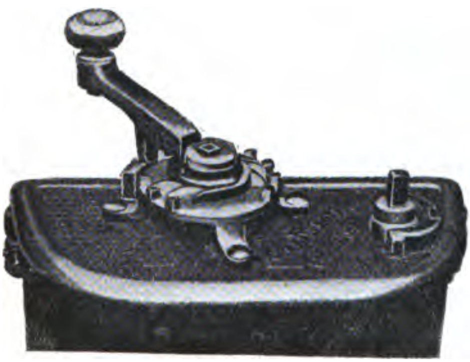


FIG. 63.



The latch does not engage in the notches when the handle is being moved back to the "off" position; and the device can be made to allow of the rate of feeding being such as will insure the most economical results.

CHAPTER V.

BRAKES.

Car Brakes.—The brake gear and rigging form an important item in the car equipment, and many different types are in use, arranged to be operated by hand or power.

Hand Brakes.—The usual arrangement for hand working is where brake blocks are applied to the car wheels through the medium of rods and levers, actuated from a handle on the car platform.

The system of levers employed is such that the blocks are pressed very strongly against all the car wheels when the platform handle is pulled round by the motorman, and the friction thus produced tends to stop the car with a force depending on the pressure applied to the wheels and on the condition of the track rails.

Brake Staff.—The brake spindle on the platform is generally fitted with a "ratchet head," so that the handle can be set to the most convenient position for working.

When the brake spindle is turned a chain is wound round the lower end (Fig. 64), and draws forward the "draw rod" attached to the brake gear under the car.

To hold the spindle in position, so that the ratchet handle may be set or the brake held permanently on after the car has stopped, a foot "dog" or catch is provided as shown.

Geared Hand Brakes.—Some forms of brake spindles are arranged with gearing at the bottom to obtain more purchase on the chain and thus reduce the amount of work thrown on the motorman.

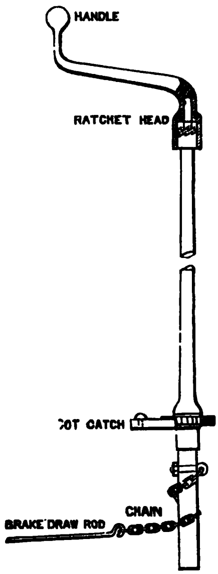
Another arrangement sometimes employed is to operate the brakes by long hand levers on the platform, similar to those in use in railway signal cabins.

Brake Rigging.—The car truck carries the brake gear,

and different types of gear are employed, according to the make of truck in use.

As representing the usual practice the diagram (Fig. 65) may be useful, and shows the fittings for a single four-wheel truck.

FIG. 62.



BRAKE STAFF AND FITTINGS.

The chain from the brake spindle is attached to the end of the lever arm, which it pulls forward, thus causing the two brake beams to separate from each other.

The inside beam moves towards the car axle, and the other moves away from it.

The beam pushed towards the axle carries at each end a heavy cast-iron shoe, which is pressed hard against the rims of the car wheels.

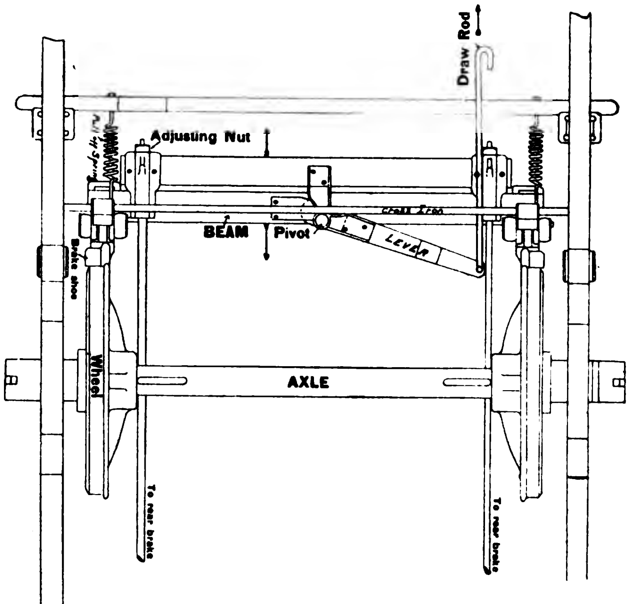
The other brake beam is connected by two rods to the beam at the other end of the truck, so that blocks are also applied to the rear wheels.

When the brake chain is slackened by the motorman

the shoes are pulled clear of the car wheels by strong spiral springs.

The long rods which connect the front and rear brake beams are screwed at the ends and fitted with nuts so that the shoes may be adjusted to brake equally on all the wheels.

FIG. 65.



BRAKE RIGGING ON BRILL TRUCK.

Rear Brake.—It will be noticed that the brakes can only be operated properly from one platform at one time, and it is necessary to slack off the chain at one end if the brake is to be worked from the other platform.

Slipper Brakes.—Another form of hand operated brake is one where a long "slipper" faced with wood is applied to the surface of each track rail.

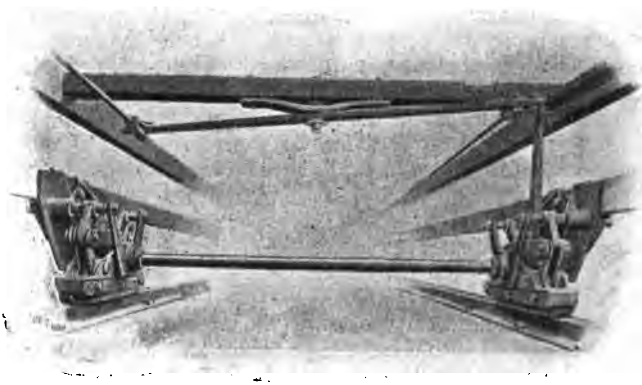
This style of **track** brake is suitable for use in descending steep grades, and is operated by a wheel or lever conveniently arranged alongside the handle for applying the ordinary wheel brakes.

An example of this class of brake is given in Fig. 66, where it will be seen that the track shoes can be pressed strongly down on the rails by a system of levers and toggles arranged to work from the platform by the usual chain.

The hard wood blocks which are attached to the slippers can be removed at any time when they become worn.

Momentum Brakes.—To reduce the work thrown on

FIG. 56.



BRITISH ELECTRIC CAR COMPANY'S TRACK BRAKE.

the motorman when stopping the car, several arrangements have been devised by engineers to take advantage of the momentum of the vehicle and apply the brakes by this means.

In the Price momentum brake there is a sleeve which runs loose on the car axle and can be coupled thereto by a friction clutch operated by the motorman.

To the sleeve is attached a chain from the ordinary brake rigging on the truck.

When the car is running and the sleeve is made to engage with the axle the chain is wound up, and tightens the brake shoes against the car wheels.

The motorman has merely to operate the friction clutch, and is thus relieved of the labour usually spent in applying the brakes.

Air Brakes.—Another method of operating car brakes is to employ compressed air to do the work.

The air is admitted into a cylinder under the car, and acts on a piston connected to the ordinary hand brake rigging.

The air is compressed by means of a small air pump, and is stored in a reservoir at a pressure of about 70 lbs. per square inch.

The air pump may be driven by gearing from the car axle, or it may be worked by a small electro-motor with current taken from the trolley wire.

An automatic regulator is fitted so that the pressure in the reservoir is kept constant. When the pressure becomes reduced the regulator starts the pump, and when full pressure is restored the pump is either stopped altogether or discharges into the atmosphere.

A pressure gauge is fitted on the platform so that the motorman may see what pressure of air is available for braking.

Platform Valve.—From the air reservoir a pipe is taken to the platform where the "operating valve" is fixed, and from the valve another pipe is led to the brake cylinder.

When it is necessary to apply the brakes the operating valve is turned into a certain position, and allows the air from the reservoir to enter the brake cylinder and push out the piston and piston rod.

To slack off the brakes the operating valve must be turned so as to allow the air to escape from the cylinder into the atmosphere, and thus allow the piston to be drawn back into its original position by a strong spring and the brake shoes to fall back from the car wheels.

Christensen Air Brakes.—The Christensen air brake equipments are arranged with either axle-driven or motor-driven compressors.

Motor-Driven Equipment.—A complete motor-driven set is shown in Fig. 67, and consists of the following essential parts:

(*a*) The **motor and compressor** which furnishes the compressed air.

(*b*) The **switch and fuse** for the motor.

(*c*) The **automatic regulator** which starts and stops the motor according to the variation of air pressure in the reservoir.

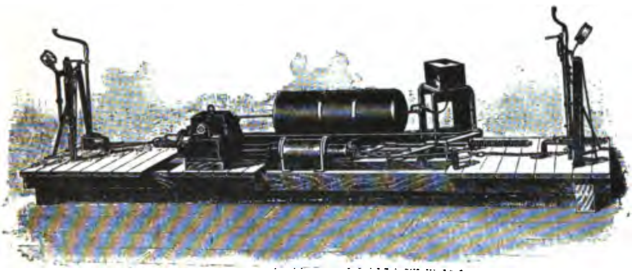
(*d*) The **main reservoir** for containing the compressed air.

(*e*) The motorman's **operating valve** by which air is admitted to the brake cylinder from the reservoir, or discharged from the cylinder to the atmosphere.

(*f*) The **air gauge** for showing the pressure in the reservoir. (Another gauge is sometimes fitted to show the pressure existing in the brake cylinder, or a single gauge having two pointers may be fitted.)

(*g*) The **brake cylinder** provided with a piston having its rod attached to the brake lever system on the car truck.

FIG. 67.



CHRISTENSEN AIR BRAKE EQUIPMENT.

(*h*) The **train pipe**, which extends from one end of the car to the other, and is connected to the driver's valve at each end.

Motorman's Valve.—The motorman's valve is shown in Fig. 68, together with a diagram of the positions in which the handle may be placed.

The handle can be removed from the valve or replaced at the **lap position** only. In this position the valve has all its openings closed and is rendered neutral.

How to Operate.—When the car is running the valve should be placed in the **slow release and running** position.

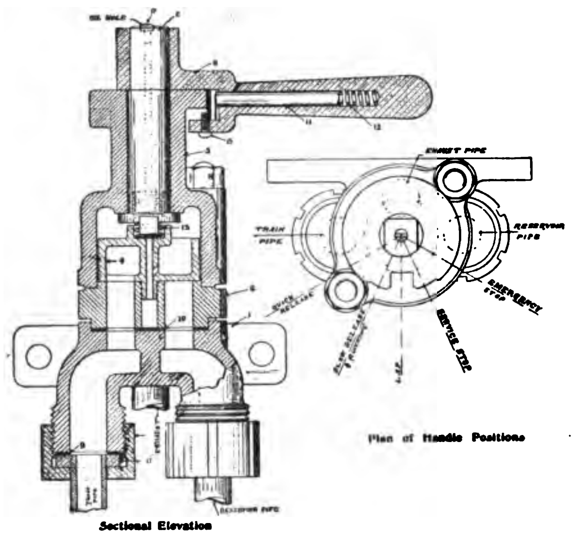
To apply the brake for an ordinary stop the valve is moved to the **service stop** position, and this allows air to pass to the brake cylinder through a small opening.

The piston applying the brake is pushed out slowly and the car stopped without jerking.

The motorman may, after admitting sufficient air to the cylinder to apply the brakes, bring the valve back to the **lap** position, when the brake will still remain on.

To release the brake the valve is moved to **slow release and running** position, which allows the air to slowly escape from the cylinder. By moving to **quick**

FIG. 68.



MOTORMAN'S VALVE AND POSITIONS.

release position the air is allowed to escape very quickly from the cylinder.

When the valve is brought to **emergency stop** position the air from the reservoir is allowed to flow through a large passage to the cylinder, thus putting the brakes on instantly and with maximum force.

Generally the brake leverage and the size of the brake cylinder are so proportioned that under ordinary circumstances with a dry rail the car wheels will not skid. If the rails are greasy the wheels will skid if the brake is

applied with maximum pressure, so under these conditions the motorman must be careful not to allow too much air to enter the brake cylinder, and if the wheels commence to skid at any time he must move back the valve handle to "**slow release**" to allow a little air to escape and let the brake slacken off slightly.

As the car comes to a stop the valve should be moved to **slow release** to prevent the disagreeable lurch the car may make. When coasting down hill the valve should be moved over to **service-stop** position for a little and then back to **lap position.**

If too little air has been admitted to the cylinder the application may be repeated, or if the brake has been applied too strongly the handle may be moved for a second or two to the slow release position and then back to lap. The driver should endeavour to manipulate the valve so that the car is brought to a standstill with one charge of air in the cylinder.

He should not make a hard application when approaching a stopping place, and then have to release the brakes and make a fresh trial.

Care must be taken not to apply too much pressure, as the wheels may skid, and even though the air is released smartly, flats may be formed on the rims and cause trouble.

Changing ends.—When changing ends at a terminus the brake may be left on and the valve handle taken to the other platform, where the brake may be released when found necessary.

Never run with the valve-handle in the **lap** position, except when the brakes are applied.

Starting the Compressor.—To start the air compressor it is only necessary to close the small switch provided, which will allow current from the trolley to reach the automatic governor.

Automatic Governor.—If the pressure of air in the reservoir is low the governor closes the circuit and allows the current to reach the motor which drives the air pump.

The motor continues to run until the reservoir pressure rises to the proper amount, when the governor cuts off the current and stops the motor until again required. The pressure in the reservoir is kept at about 70 lbs. minimum to 80 or 90 lbs. maximum per square inch.

Faults.—If the motor-driven compressor fails to start,

the trouble may be due to the fuse having blown, or possibly to a defect in the automatic governor.

If the pressure in the reservoir passes the maximum or fails to attain it after sufficient time the trouble may be due to the governor, which may need cleaning or may be clogged with some foreign substance.

If the brakes slack off after being applied in the usual way, and while the valve is at lap position, the air may be escaping from the brake cylinder through a leak in one of the pipes, or the piston may not be fitting the cylinder properly.

Axle-driven Compressor.—The Christensen axle-driven equipment is similar in principle to the motor-driven set described, except that the air-pump is mounted on the car axle and driven continuously so long as the car is running.

The air from the compressor is taken to a large reservoir as usual, and passes through the governor before entering it.

The governor is so constructed that when the pressure in the reservoir reaches a certain maximum (about ninety pounds per square inch) it opens a small valve and allows the air from the compressor to discharge freely into the atmosphere.

When the reservoir pressure falls, either through the application of the brake or from other causes, the governor closes the opening to the atmosphere, and the compressor pumps air into the reservoir until the maximum pressure is again attained.

The operating valve and general equipment of the axle-driven brake set are similar to the motor-driven equipment, and the instructions given regarding the application of the brake are exactly the same in both instances.

Air Track Brakes.—Another form of compressed air brake is shown in Fig. 69, and acts on the track instead of against the wheels.

Referring to the sectional view of the brake cylinder its action will be easily understood.

The compressed air is admitted through an orifice into the cylinder (A) and presses down the piston (B), thus forcing the wood-faced slipper (H) into frictional contact with the rail (K).

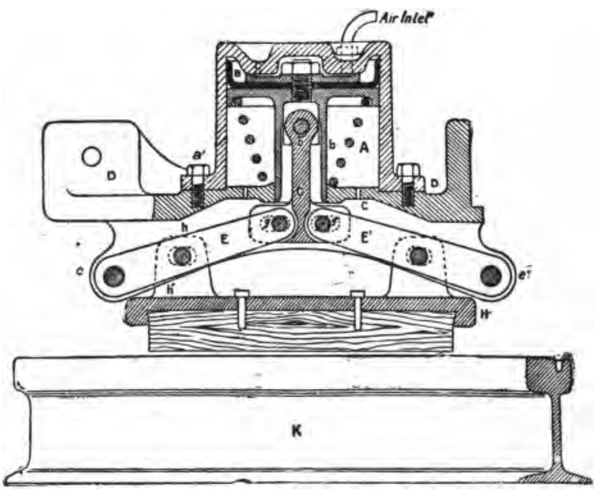
Car Equipment.—Four of these brake cylinders are

fitted to a car, and are all connected by air-pipes to the controlling valve fixed on the car platform.

A supply of compressed air is kept under the car in a strong reservoir at a pressure of about sixty pounds per square inch.

The air compressor may be driven by a small motor, or by the axle of the car through gearing.

FIG. 69.



SECTION OF HEWITT AND RHODES' AIR TRACK BRAKE.

A pressure-gauge is fitted to show the pressure of air in the reservoir.

This form of air-brake is useful for descending steep grades or for making rapid stops to prevent accidents, and is operated in the same way as the air-brakes previously described.

Reservoir Systems.—Instead of having an air compressor on every car on the system, a larger reservoir is sometimes fitted and is filled with compressed air at the depôt or at some convenient point along the route, where a large compressor is installed.

This arrangement reduces the cost of the brake equip-

ment for each car, but delays the car a little when the reservoir requires replenishing.

Electric Brakes.—A strong brake action can be produced when the car is running, by connecting the motors so that they generate current.

The application and regulation of this electric "brake" is effected by the car controller slightly modified, and arranged with additional notches, so that the amount of current produced by the motors may be varied as required.

Brake Notches.—When the controller handle is moved to the "brake" notches while the car is running, the motors are connected as generators in parallel, and the current produced is absorbed in the ordinary car rheostat.

It is to be noted that the motors can only generate current so long as the car is moving, and therefore the car will not remain stationary if on a grade, but will slowly work its way down to the foot of the incline unless held at rest by the hand-brake.

In Chapter IV on controllers, the connections on the "brake" notches of different types of controllers are described and explained.

"Emergency Stop" Positions.—On some controllers no brake notches are provided, but the reversing lever can be pulled into an "emergency stop" position where the motors are simply short-circuited, and pull the car up with a jerk.

With controllers arranged with several brake points it is possible to apply the braking effect gradually or with full force as required.

The whole of the braking effect is done by the motors through the gear-wheels of the running car.

Applying Electric Brakes.—To apply the electric brake it is necessary to move the controller handle round to the brake notch which agrees with the speed at the moment, and then to move it again notch after notch as the car slows down until the last point is reached and the car comes to a standstill.

Rapid Stops.—This form of car brake is powerful in action, and very rapid stops can be made if care is taken to apply it quickly to the notch which gives maximum effect without actually skidding the wheels.

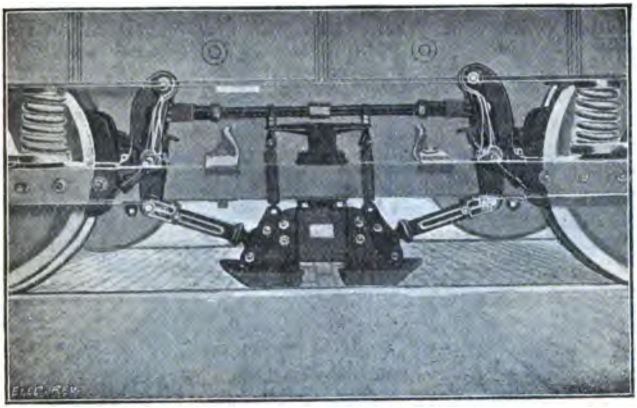
It is therefore necessary to consider the speed at the moment and the condition of the rails to obtain best effects.

Service Stops.—For making ordinary service stops

the brake should be applied as smoothly as possible, to avoid damaging the motors or jerking the car and passengers.

Electro-magnetic Brakes.—As the "rheostatic" electric brake described above is somewhat severe on the motors, several arrangements have been devised by engineers in order that a portion of the current spent in simply heating the rheostat may be usefully employed in retarding the car's progress.

Fig. 70.



Westinghouse Magnetic Brake.

The usual idea is to pass the current from the motors through the coils of large electro-magnets, which operate brake gearing on the car axles and wheels or on the track rails.

Newell Brake.—A type of magnetic brake is shown in Fig. 70, which acts on the car wheels and also on the track.

In this case the motor current, after passing through the controller and rheostat, reaches the coil of the large magnet, which hangs immediately over the rail, causing the magnet to cling to the track and act as a slipper brake.

The car, running forward, pushes the track magnet along, and by an arrangement of pivoted levers and rods brake-shoes are applied to the wheels of the car.

Acts on Axles, Wheels, and Track.—It will be understood that with this type of magnetic brake not only is the car retarded by the work thrown on its motors, but the current produced is to some extent usefully employed in actuating the brakes on the wheels and rails.

The track magnet is supported clear of the rails by spiral springs when the brake current is off.

Thomson-Houston Magnetic Brakes.—Another form of magnetic brake is given in Fig. 71, and consists of a large magnet, which is attracted strongly to the rail when excited by current from the car motors.

Fig. 71.

Thomson-Houston Magnetic Track Brake.

When the controller is moved back to "off" position, or when the car stops, the magnet is pulled up clear of the track by suitable springs.

Two magnets are fitted on single trucks, and four on double-truck cars.

The downward drag produced by the magnets tends to slightly increase the weight on the car wheels and prevent skidding.

Magnetic Disc Brakes.—Instead of employing electro-magnets arranged to be attracted to the rails, they may be constructed in the form of discs and mounted on the car axle.

With this style of magnetic brake the usual arrangement is to have a flat disc keyed to the axle and running

close to another disc which is held stationary on suitable supports. The stationary disc has coils of insulated wire imbedded in it, and when current from the motors is allowed to pass through the coils the axle-disc is strongly attracted, and the friction produced between the two discs tends to stop the wheels from revolving, and bring the car to rest.

Operating Magnetic Brakes.—With all the magnetic brakes mentioned the operation is practically the same as for the rheostatic electric brake, and the same care is necessary to prevent jolting the car or damaging the motors.

"Regenerative" Braking.—From what has been mentioned previously regarding electric brakes the reader will understand that the current produced by the car motors may be regulated in amount by varying the amount of rheostat, and may be employed to operate track or wheel brakes.

The motor current may also be used to heat the car interior by passing it through suitable resistance coils.

Instead of using the current in any of these ways it may be returned to the trolley wire, and thus serve to drive other cars on the line.

The special apparatus used in connection with regenerative control is described in another section of this book.

CHAPTER VI.

ON THE ROAD.

Rules and Regulations.—So many different equipments and types of apparatus are in use on the various lines in this country that it would be impossible, within the limited compass of this small handbook, to describe in close detail the exact method of operating such apparatus, and as different rules and regulations are issued by each company or corporation, no attempt will be made to lay down a hard and fast code of instructions for the motorman, but rather a general outline of how he may safely and efficiently operate his car and deal with such troubles as may arise.

First Essentials.—Motormen should remember that as public servants they may often find it necessary to exercise great patience and self-control in performing their duties and in dealing with dissatisfied people, but they will usually find that a cheery and polite reply will do much towards smoothing down any dispute which may occur.

When handling a car it is necessary to remember that the safety of the public is the first consideration, and that strict temperance is absolutely essential while on duty.

Reporting at Depôt.—In starting the day's work a motorman should report at the car depôt with plenty of time to spare, so that he may read any fresh notices which have been issued by the management, and have a look round the car allotted to him for the day.

Examine Car.—He should try both controllers to see they are working freely, examine all main switches and cut-outs for proper working, and try all the car lights and bells, together with the foot-gongs and sanding gear, and any other appliance necessary in running the car.

He should see that the hand brakes are working pro-

perly, and have a glance round to see that the car is equipped with point-shifter, spare fuses and lamps, rubber gloves, ramp, and other tools according to the usual arrangements.

Leaving the Depôt.—Before starting the car the driver must see that the rear brake is off, that there is no person working underneath in the pit, and that the conductor has hold of the trolley cord to guide the pole round the sharp bends and curves generally existing in car sheds.

Going out of the depôt the speed must not exceed four miles per hour until clear of all points and crossings, and as soon as possible a test should be made with the various brakes with which the car is fitted.

If the brakes are found defective, or the motors or controllers not in working order, the car should return to the depôt for examination by the engineers, or another car may be secured.

Starting from Terminus.—Assuming that the car and equipment are in perfect order, the motorman proceeds on his way to the route starting-point, where he sees that the trolley-pole is turned in the right direction, with the wheel on the right wire, and that the controller handles, foot-tramps, and other platform gear are placed at the driving end of the car ready for starting.

On receiving the signal from the conductor he puts the reversing lever of the controller forward and brings the large handle smartly to the first "power" point, at the same time easing off the brake so that the car starts without jerking or straining.

A slight tap of the foot-gong should be given when starting, to warn passengers.

"Feeding up" Controller.—The controller handle is now brought gradually round to the first **running** point,—the full series,—each notch being rested on for such time as is necessary for the car to attain speed, and care must be taken that the handle is never allowed to rest between the notches, or slipped past a point without resting on it for the proper time.

If the speed of the car on the first running point is too slow the controller must be moved point by point to the second running notch,—the full parallel,—and the motorman, standing erect with one hand on the controller and the other on the brake handle, keeps a sharp look-out for vehicles and pedestrians in front or crossing the track.

Switching off Power.—On approaching a stopping place or nearing an obstruction the controller is switched right "off" with one smart movement and the car allowed to run by its own weight until it becomes necessary to apply the brakes, which should be done gradually, and the car brought smoothly to a standstill exactly at the station or at a safe distance from the obstruction on the track.

Greasy Rails.—If the track is greasy and slippery, and it is found necessary to stop quickly, a little sand dropped on the rails will cause the car wheels to secure a good grip and prevent sliding or "skidding" them.

Skidding Wheels.—It is important to note that the brakes must never be applied so strongly as to keep the wheels skidding, as when this is done the braking effect is greatly reduced, and the car may slide forward a considerable distance, particularly when the track is greasy and the car is descending a steep incline.

Skidding is liable to damage the car wheels, and although it is sometimes difficult for the motorman to tell if the wheels are sliding or if it is simply a greasy rail, he should, if at all doubtful, slightly ease the brakes off and on to let the wheels revolve to some extent, and may apply a little sand until he feels the car well under control.

Setting Hand Brake.—When the ratchet handle of the brake has been set into the proper position it should be kept there, so that the motorman may know just where it will come to when the brake blocks are hard against the wheels.

Do not let the handle fly round at any time, as it annoys and alarms the passengers.

When the rails are slippery great care must be exercised to prevent the car from getting beyond control, and when approaching obstacles the speed must be kept within safe limits and no risks taken.

Rear Wheels Skid.—Sometimes the rear wheels of the car may start skidding first, as most of the weight is taken by the front axle when the car is running forward, especially on down grades.

In the same way where the car is fitted with double trucks the wheels of the rear truck are more liable to start skidding when the brakes are applied hard.

Quick Stops.—When power brakes are fitted to the car, and a quick stop is required, the ordinary hand brake

may remain off and the power brake be applied to effect a rapid halt to avoid accidents.

Caution at Cross Streets, etc.—A warning tap of the gong should be given when approaching cross streets or passing a car on the opposite track, and when the other car is discharging passengers a bright look-out must be kept for anyone coming out from behind, and everything held ready for making a rapid stop if found necessary.

Traffic Cautions.—Avoid running up close to vehicles in front, and always make sure before passing them that they are clear of the track and not likely to swing round into side streets or lanes, and perhaps strike the car body with a projecting load.

When approaching a stopping place where there is not sufficient room for vehicles to draw clear of the rails, do not keep "ding-donging" at the gong, but follow slowly after the vehicle to the station, and give the driver a fair chance to draw clear further on and allow your car to pass.

A motorman soon gets acquainted with the local carters and lorrymen, and can exercise a "give and take" policy with considerable advantage to himself.

Look out for Children.—The driver must keep his eye on pedestrians crossing the street with their backs turned towards him, and for children swinging on the rear end of cars and other vehicles.

When passing schools and public institutions the utmost care should be exercised to prevent accidents.

Passing Horses.—When passing close to heavily laden horses the motorman should be ready to stop at once, as the horse may stumble and swerve across the track before the car and cause a nasty accident.

Horses standing at the side of the street without attendants may wheel round on hearing an approaching car; or even if the driver is present, he may turn the vehicle across the track unless he receives full warning from the gong and whistle.

If horses become restive as the car is passing them, the driver should slow down, and, if necessary, stop altogether until they calm down.

The motorman should speak if a horse is restive, and this will to some extent lessen the fear of the animal.

If the road is greasy and a horse is unable to start its

load, a handful of sand may be thrown at its feet to assist it out of the way.

When any vehicle becomes disabled and is blocking the track, the motorman should leave the car in charge of the conductor and assist to clear the road to prevent stoppage of traffic.

Cautions at Cross-Overs, etc.—Keep a look-out for cars swinging out of side-lyes or turning at cross-overs, as a considerable number of serious collisions occur at these places, owing to want of care on the part of the motormen.

Conductor's Signals.—Always insist on the conductor giving clear and distinct signals, and do not start if in doubt at any time as to the meaning of the signal given.

Look out for Passengers.—Keep a sharp look-out for passengers wishing to board the car at stopping places and cross streets. Remember you are running the car to collect passengers, and not simply for your own amusement.

Overtaking Cars.—When overtaking a car in front do not run close up, but always endeavour to keep some considerable distance between cars going over the same route.

It looks bad to see three or four cars all running close together and leaving a gap of half a mile or so between them and the next car.

Cross Traffic.—When overtaking a car at a stopping place always leave room for people to get across the street, and at cross streets room must be left for all cross traffic.

Passing Section Insulators.—As the car passes under a section insulator the controller must be switched "off" until the trolley wheel has passed, and care should be taken not to stop the car with the trolley resting directly on the insulator.

If this latter occurs the brake should be eased off to allow the car to run some little distance from the insulator, or, if on a dead level, the pole may be turned to make contact with the live trolley wire and the car be moved ahead.

Facing Points and Crossings.—Very great caution must be exercised when approaching facing points, as the wheels may take the wrong line, and a collision result with an approaching car or vehicle on the other track.

Always slow down at all crossings and points, to prevent jolting the car and damaging the trucks and wheels.

Obstructions on Track.—Keep a look-out for articles

lying on or between the rails, and always remove anything likely to cause damage to the cars.

Even a small piece of iron lying on the rail may break or bend a car axle, and any hard substance in the rail groove may chip and break the flanges of the wheels.

Avoid Racing.—Avoid racing with other vehicles to secure first place at junctions. During fog, or when running on badly lighted roads, be careful to reduce the speed so that a stop may easily be made in the distance clearly seen ahead, and never take it for granted that the line is clear.

Reducing Speed.—If it is necessary at any time to reduce speed the controller must be brought smartly to the off position, and afterwards fed up to the position desired.

Feeding Controller when Running.—When the controller is switched off for a little, as is necessary at a section insulator or when passing a car on the opposite track, the motorman need not feed up again so slowly as when starting from rest, but should move the handle round at once to the notch which agrees with the speed at which the car is actually travelling at the moment, and then feed up to full speed as usual from that point.

Care must be taken not to swing the controller round past the proper notch, as the car may receive a severe jerk, or the automatic switch may open.

Operation of Controller.—When switching off the controller do not use too much force, as it may damage the mechanism considerably and cause unnecessary wear and tear.

On no account is the controller to be moved back a notch or two; it must be moved right "off."

Never move back from the first power notch when starting the car from rest, as it may burn the contacts severely. In fact, it is always better to wait until the car has got into motion or feed up to the second notch before switching off.

From Series to Parallel.—Always move quickly from the last series notch to the first parallel one, as only one motor is in operation for the moment when changing the connections from series to parallel, and a heavy flash may be set up at the controller contacts if moved slowly round.

How to Start the Car.—When starting a car from rest the motorman should remember that to turn the current

on too quickly may cause the wheels to slip and not secure the best tractive grip on the rails.

When the motors are connected in series the same current is passing through both, and more value is got from the current for accelerating than when the motors are in parallel and each receiving half the total current taken from the line.

It is important, therefore, for the motorman to get as much acceleration on full series as possible before moving round to the parallel positions.

Rule for Acceleration.—A general rule for acceleration on the level is to increase the speed of the car at the rate of one and a half miles per hour per second. For example: on a car designed to run at a maximum speed of eighteen miles per hour on the level the controller handle may be moved round from the first to the last position in, say, ten seconds.

For cars designed to run at higher speeds the controller handle will require to be moved round at a slower rate, and for lower speed cars it may be fed up more quickly.

When the line is a small one the motorman should be careful not to start the car very quickly, as it throws an unnecessary strain on the machinery in the power station, and also causes a loss of power in the feeder cables and return circuit.

Starting on Greasy Rails.—In starting the car on a greasy rail the controller handle should never be brought past the first notch until the wheels have gripped the track and the car has got well started.

If the wheels are allowed to fly round when starting, and sand is dropped freely on the rails, a great strain is thrown on the motors and gearing. The motorman should therefore get the wheels to grip when the first notch is applied, and gradually increase the power as the car accelerates in speed.

Should the wheels again slip, switch right off and feed up again, at the same time applying sand.

Stopping on Hills.—When coming to a standstill on a hill or greasy track a little sand may be dropped, so that the car comes to rest on the sand, and is able to start off again without slipping.

Avoid stopping on hills or curves if possible, as it requires a great effort to get up speed again, and consumes extra current.

Running Notches.—Only the full series and full parallel notches are to be employed for continuous running.

The intermediate points are to be used for starting up the car, and must not be used for any length of time, otherwise a large proportion of the current is wasted in simply heating up the rheostat, and is not used to propel the car.

How Rheostats are Damaged.—Again, running for long periods on the resistance notches is apt to damage the rheostat or make one section hotter than another, and thus affect the smooth working of the car in starting or in stopping with the electric brake.

Running on "Full Series."—After coming to the full-series notch the car should be allowed to attain its maximum speed on that point before moving further round, otherwise power is wasted needlessly.

For heavy pulling on inclines the full-series notch is easiest on the motors, but is generally too slow for every-day work, and as cars are usually fitted with motors of sufficient power to mount the steepest hills without undue straining, it is preferable to run at full parallel, and thus climb the hill quicker and save current and time.

Coasting.—When a motorman is learning his business he is rather apt to apply the brakes too strongly, and often throws a lot of unnecessary work on himself which could be avoided by the exercise of a little judgment and coolness.

When a car is running fast it represents a considerable amount of stored energy, which will cause it to run a long distance after the controller is switched off.

A skilful motorman, by correctly estimating the distance he can coast with power off, will be able to run with very little exertion spent on the brakes, and with a much less consumption of current from the trolley wire.

Economy in Current.—Of course, on some routes where the time is cut down to a minimum, or when the car has been delayed, it is necessary to approach stopping places at rather high speeds, but there is always plenty of scope for economising in current consumption during a complete journey or in a full day's work.

When recording meters have been fitted on cars and systematic tests made it has been found that an intelligent and expert driver can run his car with much less current

than a careless or ignorant motorman, while at the same time keeping up to time and collecting as many passengers.

How to save Power.—The main point is to take advantage of all grades to run with power off, and to switch off as soon as possible when approaching stations or obstructions, and allow the car to drift along by its own momentum.

When starting the car it is important not to rest too long on the resistance notches, especially the parallel ones, but to feed up the power properly as the car accelerates, always taking into account the nature of the track and the power and weight of the car.

The full-series notch may be used for slow running through traffic or when only a short distance has to be traversed before stopping, but on a clear road the full parallel notch should be employed, as the current is then being used to the best advantage and the most economical results obtained.

When approaching a steep incline, endeavour to get up speed before striking the rise.

Speed at Curves, etc.—When approaching curves slow down to a safe speed (four miles per hour), as a great strain is thrown on the car axles and truck if taken round sharp bends at high speeds, and the trolley is very apt to leave the wire at these points.

When running through cross-overs, frogs, and complicated overhead junctions, always run slowly and with power off if possible, and be ready to stop instantly should the trolley leave the wire.

Trolley off.—A motorman can usually detect the instant the trolley jumps the wire by the sudden slackening in speed if the controller is on, or by the quiver of the trolley wire in front, and by stopping the car promptly he may prevent considerable damage being done to the pole and line.

Replacing Pole.—When the pole springs off at any time care should be taken not to allow it to rub against the trolley wire, as the usual protective tape on the pole may be wet or worn off, and the current from the trolley wire may get to ground and cause the "ground indicator" to act, if such appliance is fitted on the car, or if the trolley standard is directly connected to the rails the rush of current from the trolley to the rails may open the station circuit-breaker and render a long section of the

route dead. Only the "head" of the pole should be allowed to touch the trolley wire.

Neither must the pole be allowed to touch both guard and trolley wires at the same instant, or a short circuit may be established and burn the wires through or open the station circuit-breakers.

Reversing Car.—When it is necessary to set back the car the conductor should be signalled and the car moved very slowly back, after seeing that the line is clear to the rear.

It is advisable to turn the pole into the proper direction before running backward, especially at curves or at crossings of the overhead wires.

Emergency Stops.—Sometimes it may be necessary to stop the car very quickly to prevent an accident, and in such emergencies very much depends on the coolness and promptitude of the driver.

The power brake with which the car is fitted should be applied at once, and sand dropped as freely as possible on the track to prevent the wheels skidding and to secure the best possible braking effect.

Reckless Motormen.—Occasionally it may be impossible to stop a car in time owing to another vehicle drawing suddenly across the track, or the rails may be unusually greasy, but an alert and cool motorman, by prompt action and good judgment, can very often avert a collision where a foolish or reckless man would fail.

It is no credit to a motorman to allow his car to get beyond control at any time, or to take dangerous risks when he is perfectly well aware that his car cannot be stopped in the distance at disposal.

It should always be kept in mind that on a given line a car can only be stopped in a certain minimum distance, and that to throw the brakes on so hard as to skid the wheels is certainly a foolish proceeding if good results are required to prevent an accident.

Descending Steep Grades.—Before descending long steep grades particular attention should be paid to the condition of all the brakes, both hand and power, and the sanding gear tried, so that the hill may be descended safely, and an emergency stop made if found necessary on the way down.

Avoid letting the car attain a high speed during the descent, as the braking power necessary to stop increases

greatly with the higher speeds, and the wheels may start skidding if the rails are at all greasy.

Skidding on Grades.—If the wheels start skidding when descending a hill the brake should be eased off slightly and sand dropped until the car is well under control.

On no account is sand to be dropped while the wheels are locked, or they may be badly damaged thereby.

When a mechanical slipper brake acting on the rails is fitted to the car it is usual to apply it slightly at the top of the hill, so that it may readily be brought into action to effect a quick stop, or it may be used to control the car all the way down if the grade is very steep.

To prevent Cars running back.—On some lines, where the grades are very severe, the cars are fitted with a device which is brought into operation when on the ascent, and which prevents all possibility of the car running back down the hill, by slipping under the wheels and "spragging" them immediately the car starts backwards.

Power off Line.—If the power is cut off from the trolley wire at any time the controller handle must be brought to the "off" position and the car lights switched on, so that you may see when power is again restored.

If the power has been off for some time, and a considerable number of cars have to start, do not pass the half-speed notch for a few minutes, so as to give the power station a chance to take up the load, and each car should be allowed to get into motion before the others put on power.

Leaving Platform.—A motorman should never leave the car platform without first switching off the current and taking the controller handles with him.

He should also see that the car brakes are left on, so that there may be no risk of a runaway occurring.

Track under Repair.—If the track is being examined or repaired the motorman must be careful to slow down at such points and give ample warning of his approach, so that the workmen may have time to remove any obstructions from the line.

Tower Wagon.—When the tower-wagon staff is at work on the line, stop the car at a safe distance and ascertain whether you may run past.

The conductor should be ready to pull down the trolley-pole if the platform of the wagon is turned across the

track, and the car should get up sufficient speed to coast past with power off.

Disabled Cars.—In the event of a car becoming disabled in a busy street it should be pulled or pushed out of the way by another car to prevent stoppage to the service.

When a disabled car is being pushed by another, the driver of the rear car should arrange to get signals from the driver of the first car and also from the conductor of his own car before starting.

The driver of the front car stands ready to signal in the usual way if a stop is found necessary, and the two cars are only allowed to run at a slow rate, especially on grades or at curves and points.

When towing or pushing another car the pole of the car not in use must be tied securely down, clear of all bridges.

Unusual Noises.—Any unusual noise in the car should be attended to at once, to prevent a breakdown occurring.

Bent Axles.—If an axle becomes bent it may cause the car to swing when running, and the car must be run slowly at points and curves where it is liable to be derailed.

Broken Wheel Flanges.—The flanges of the wheels after long running become thin, and are liable to crack and break off, and may catch on the brake blocks when these are applied by the driver.

Rain and Dirt in Controller.—The door of the controller must always be kept properly closed, to prevent dust getting inside and causing bad contact at the fingers and drum.

If rain penetrates to the interior of the controller it may cause the current to leak from the "live" parts to the outer case, and may charge the case so that the motorman receives a shock on touching it. If the controller case is connected to the rails, as is usually done, the rush of current caused by the leak may blow the car automatic switch or safety fuse.

"Ground" on Controller.—When a leak occurs in a controller it generally shows its presence by a heavy flash, or by smoke issuing from the cover, and on opening the door the defect can probably be detected by the woodwork and insulation being blackened.

Snow.—Do not allow snow to accumulate on the top of the controller, as it may find a way into the case and

cause trouble. It is a good plan to carry a cotton sweat rag to wipe up any moisture in the controller, or to clean up generally.

Ice on Trolley Wire.—If the trolley wire becomes coated with sleet or ice, it may be necessary to wedge the trolley wheel to prevent it turning, and to scrape the icy covering from the wire. This should only be done with the knowledge of the line superintendent, and the car must never be set back when the wheel is wedged, otherwise the pole will be certain to buckle.

Badly Running Trolley.—If the trolley wheel leaves the wire frequently, even on straight lines, it may be due to the tension springs requiring adjustment, or the trolley head may be loose and canted to the side.

Running "Bang Road."—If at any time it becomes necessary to run on the wrong side of the road, the greatest care must be exercised to prevent collisions with other vehicles.

Getting New Car.—When a car becomes defective, and it is necessary to run it into the depôt for examination, the motorman should if possible telephone before he arrives, so that another car may be ready for him on his arrival.

Caution passing Poles.—On some lines the cars run very close to the poles which carry the trolley wire, and motormen must be cautious not to lean out from the car platform, or they may strike the pole and get knocked off the car.

How to operate Electric Brakes.—The motorman should make himself expert in the use of the electric brake if his car is fitted with it. In this case the controller will have several "brake" notches in addition to the usual "power" points, and the brake is brought into operation by moving the controller handle to these points when the car is running. On these notches the car motors are connected so that they act as **generators**, and the amount of current taken from them is regulated by the rheostat, which is all in on the first brake notch, and is gradually cut out of action as the controller handle is moved round to the last brake position.

As the motors are driven by the car wheels, it will be understood that a strong braking effect will be produced if a heavy current is demanded from them. The amount of current which the motors will generate depends on the

speed at which the car is running and on the amount of rheostat in action.

Coasting on Electric Brakes.—It becomes necessary, therefore, for the motorman to learn the value of the different brake notches, and this knowledge can best be acquired by allowing the car to coast down a grade while controlled by the electric "brake" only.

It will be found that with the controller handle on the first brake notch the car will run at a fairly high speed down the hill, and that this speed will be practically constant during the descent. If now the handle is brought round to the succeeding brake notches the speed is further reduced, until finally, on the last notch, the car comes to a standstill or runs very slowly indeed down the grade.

Electric Brake won't hold Car at rest.—If the car stops altogether the current from the motors stops and the car is free to move off again, only to be brought up by the motors at once starting to generate current and checking the motion of the wheels as before.

It will now be understood that the electric brake may bring a car to a standstill or allow it to coast down grades at various speeds, yet it is unable to hold the car stationary on inclines, and the hand brake must therefore be applied to prevent the car from slowly working down to the foot of the hill.

Application of Hand Brakes with Electric Brakes.—It is important to note that when the electric brake is used no other brake acting on the car wheels or axles is to be brought into action, or the wheels may be skidded and the generation of current by the motors stopped.

When applying the electric brake care should be taken not to bring the controller handle past the brake notch which agrees with the speed at which the car may be running, and afterwards to move slowly to the next notches, pausing on each until the full effect has been experienced.

Rapid Stops.—For very rapid stops with this brake the controller handle should be brought round rapidly to a suitable notch to give maximum effect without skidding the wheels, and sand should be dropped freely on the track; the controller handle is fed round to the last brake point as the car slows down.

Operating on Brake Notches.—When coasting down a grade with the electric brake in action the motorman may ease back a notch or two if he finds it necessary, but

he should always wait on each notch until after its full effect has been obtained, and must never move back from a notch just as the braking effect is increasing strongly.

Never switch from the first brake notch to the "off" position until the speed of the car is down to six or eight miles per hour, or until the brake has exerted its full effect on that notch, otherwise destructive flashing may occur in the motors and controllers and damage them considerably.

Magnetic Brakes.—Cars fitted with electro-magnetic brakes are operated in the same way as those fitted with the rheostatic form, and have the advantage of requiring less current from the motors to produce the same braking effect, as a portion of the power is utilised in the brake magnets instead of being wholly absorbed in heating the car rheostat.

Several types of magnetic brakes are in use, but the operation of all of these is exactly the same as for the rheostatic type.

Service Stops with Magnetic Brakes.—To effect an easy stop with the magnetic brake, care should be taken to keep the strain on the magnets once they have been brought into operation, and not to let the magnetism die away before moving to the next notch, as this may cause an unnecessary jolt to the car.

When applying the brake with the car running slowly, it is sometimes rather difficult to prevent a jolt when the brake magnets come into operation, and it will be found better to get the brake into action slightly at the higher speeds, and have the motors and magnets excited ready for any increased effort that may be necessary.

When the controller is provided with a large number of brake notches it becomes much easier to apply the electric brake smoothly at all speeds.

Magnetic Brake holds Car for a time.—It will generally be found that the magnetic brake will hold the car on an incline for a short time after bringing it to rest; but of course for long stops, or where the incline is rather steep, it will be necessary to apply the hand brake to hold the car.

With some forms of magnetic track brakes it may be found that, after bringing a car to rest on a heavy grade, a difficulty is experienced in applying the hand brake.

This may be due to the track magnets thrusting the car

axles slightly apart, and thus putting the handle of the wheel brake off the usual adjustment.

The trouble may be avoided by applying the hand brake just before the car comes to rest, and easing off the magnetic brake at the same time.

Several types of electric brakes are described in Chapter V.

Methods of stopping Car.—It may be judicious at this point to examine the different methods by which a car may be stopped when fitted with a series-parallel controller with "brake" notches.

The rules given are applicable for a car running backwards or forwards, and the motorman is advised to memorise and practise them, so that if at any time one of the methods fail he can immediately apply the next and stop the car at once.

Particular attention is called to the rules relating to the position in which the reverse lever of the controller must be placed when applying the different methods enumerated.

Hand Brake.—The first method is by the ordinary hand brake with which all electric cars are fitted, and which can be applied to stop the car running in any direction, the only precaution necessary being not to skid the wheels.

Electric Brake.—The second method is to apply the electric brake by placing the reverse lever in the **same direction** as the car is moving in, and then moving the large handle to the brake notches.

Reversing.—The third method is to reverse the motors by placing the reverse lever in the **opposite** direction to that in which the car is running, and then to bring the large handle to the first or second power notch.

Last Resort.—The fourth method is to switch off the automatic or canopy switch, and bring the large handle round to full parallel, after placing the reverse lever in the **opposite direction** to that in which the car is travelling.

Extra Brakes.—If the car is fitted with mechanical slipper brakes these can be brought into action if necessary.

Braking at Rear Platform.—A motorman should remember that if all the brakes fail to act at one platform, yet it may be possible to stop the car from the other con-

troller, or the conductor may be signalled to apply the rear hand brake, while the motorman sees it is quite free at his end.

"Emergency Stop" Controllers.—When the controller on the car is not arranged with several brake notches, but has simply an "emergency stop" position, this should be applied if the hand brakes fail, or when a rapid stop is necessary, to avoid an accident.

Runaways on Hills.—A number of accidents, due to cars getting beyond control when descending steep inclines, have been caused by the motorman applying the hand brakes so hard as to skid the wheels, and then not having the sense or courage to slack off this brake when applying the electric methods mentioned above.

Power failing when ascending grade.—When ascending a hill, and the power failing, either through the automatic switch or fuse blowing, or through the current being cut off at the power station, switch off the controller and apply the hand brake to prevent the car running backwards.

Car running back on grade.—In the event of the ordinary brakes failing to hold the car, the electric brake must be applied to the last brake notch with the reverse lever pointing **backwards,** or the reverse lever should be pulled over into the "emergency stop" position, if this type of controller is fitted on the car. Of course, if air brakes or mechanical slipper brakes are fitted, these can be used to prevent the car running back down the hill.

If it is found impossible to reduce the speed of the car with any of the above mentioned brakes, which is very improbable, the "last resort" method may be used to effect a stop, as previously described.

When stopping on a hill, and the hand brakes failing to prevent the car from running back, apply a notch of power to take the car forward, or to hold it while the rear hand brake is being applied by the conductor.

Special Controllers. – Some controllers are so arranged that they apply the electric brake automatically when the car starts running backwards; but the motorman will receive special instructions from his superintendent if his car is fitted with this unusual form of controller.

Operating Air Brakes.—When the car is equipped with compressed air brakes it is necessary for the motorman to see that the operating valve on the platform is set

to the "running" position, and that the proper pressure is reached in the air reservoir soon after leaving the depôt.

When the air-pump is driven direct by the axle of the car it will have to run a little before the reservoir becomes properly charged.

If the pump is driven by a separate small electro-motor it must be started before leaving the depôt, so as to fill up the storage tank to the proper working pressure, as indicated by the pressure gauge on the car platform.

Economy in Air.—In working with air brakes the motorman should endeavour to use as little air as possible.

When making a service stop, the operating valve should be turned round to admit air to the brake cylinder slowly, and when the brakes are acting sufficiently the valve should be moved back to stop the supply of air.

Do not apply the brake too strongly, as it will then be necessary to allow some of the air to escape, and another application may be found necessary to stop the car at the station.

To stop very quickly the air should be turned full on, while sand is dropped freely on the track rails. When the rails are slippery care must be taken not to skid the wheels, and if this occurs the operating valve must be moved quickly to the release position for a moment or two to allow the wheels to revolve.

When stopping at a station the brake should be released slightly as the car comes to rest, to avoid jolting the car.

Starting Car.—When the car has been stopped the valve should be brought to the release position to be ready to start again, and care is necessary to have the brake off when applying power to start the car from rest.

If stopping on a hill, it will be necessary to keep the brake on to prevent the car running backwards, or the hand brake may be applied to hold the car stationary while the air is allowed to escape from the brake cylinders.

Some types of air brakes are described in Chapter V, to which the reader is referred.

Running to Depôt.—After the day's work is finished and the car is running to the depôt, the motorman must still take care to run cautiously and take no risks. Although there may be no passengers aboard, the car should be run at the usual speed, and the usual caution exercised at all points and crossings.

Run slowly into the depôt, and leave the car safe for the night with the switches off and the hand brake on.

The pole should be turned and taken off (unless the lights are required by the cleaners), and must not be allowed to rub against the trolley wire.

Before going home, report to the depôt foreman any defect which may have occurred during the day, so that it may be examined and repaired.

CHAPTER VII.

FAULTS AND BREAKDOWNS.

Common Faults.—In the following pages are mentioned some of the common troubles and faults which may occur on an electric car, and the probable causes of these are stated, to enable motormen to quickly locate and rectify the defects or secure assistance without unnecessary delay.

Some of the faults mentioned can only be remedied in the depôt, but others are easily put right on the road, and the car may continue in service.

Handy Tools.—A motorman should always carry a screw-driver and a pair of cutting pliers.

A smooth file and a small piece of emery-cloth will also be found handy at times.

No Delay.—No time should be wasted when anything unusual occurs, but a start should be made to locate the defect as soon as possible, to prevent delay to other cars.

Always report any breakdown, however small, to the proper quarter, in order that the car may be examined by the depôt men at night.

Electrical Defects.—In dealing with defects on the electrical equipment it should be remembered that the car lights will serve to indicate if the power is on or off the line, and that by trying each controller separately the motorman can ascertain whether the current is getting down that length or if the fault lies in the controller or motors.

An Example.—Suppose, for example, that the car refuses to start when the controller handle is moved round as usual.

Ascertain if the pole is on the wire and if the lights will burn when switched on.

See that the main switches are "on," and also if the fuse is in proper order.

Try the car with the **rear** controller, and if it starts all right there, you may be sure that the current is getting down to the motors and that they are in working order.

The defect may be in the front controller, which should now be examined for bad contacts at the fingers and cables.

Open Circuit.—If the car refuses to start at both controllers with the car lights burning brightly, it indicates that the current is not getting down through the main switches and fuse block.

Car "Grounded."—Sometimes the car won't start owing to it having run into a dirty rail, but in such a case the lights will not burn properly, and the trouble will generally be evident on looking at the wheels and track.

Dirty Contacts.—When the contacts of a switch or a controller become burnt or dirty, they should be cleaned with fine sand-paper or carefully scraped with a knife-blade or smooth file.

It takes very little dirt to cause trouble sometimes, and when examining a controller for bad contact the motorman should start at the first finger and work carefully over the remainder, so that one examination will suffice and the car will not be delayed unduly.

Of course, it may be that the defect can be seen at once after opening the controller-door.

A little vaseline or graphite should be rubbed on a contact which has been cleaned, to prevent the surfaces cutting when in action.

Necessary Precautions.—When working with any part of the power equipment always take care to have the main switches off, to guard against receiving shocks or getting burnt.

Fuse, or Switch "Blows."—When the automatic switch "blows" or the fuse melts it indicates that too much current is being taken from the line, and this may be caused by the motorman starting the car too quickly, or by a "ground" having developed at some point of the circuit, possibly in the motors or in the controllers.

Detecting Leak.—To ascertain where the leak exists it is necessary to cut out first one motor and then the other, unless the defect is plainly evident elsewhere.

Cutting out Motors.—When cutting out a defective motor from circuit by means of the "cut-outs" in the controller, it is advisable to do so at both ends to prevent trouble when driving the car from the other platform.

Only one motor should be cut out at a time, as when both "cut-outs" are moved over the connections made are such that the trolley current gets direct to the rails, and the switch or fuse would "blow" when the controller handle was brought to the power notches.

Running with one Motor.—When running with one motor care should be taken to start slowly and run easy in order not to strain the motor unduly.

Leak in a Motor.—If a leak develops on No. 1 motor the switch or fuse will probably blow before the third or fourth notch is reached, but if the defect is in No. 2 motor they may not blow until the full-series notch is passed.

Cause of Leak.—Generally a ground in a motor is caused by the covering of the armature coils becoming damaged, or it may be due to carbon dust and oil gathering at the end of the commutator or on the brush rocker, and allowing the current to get to the motor-shaft and rails.

Ground in Magnet Coils.—Again, the leak may occur on the field-magnet coils, and cause an abnormal rush of current to "earth."

Short Circuits.—When a "short circuit" occurs between the segments of a commutator or between two armature coils the motor will spark violently, and the defective coil will overheat and become charred.

Open Circuit.—If a broken connection occurs in an armature it will show its presence by causing heavy flashes at each revolution.

Weak Fields.—When a "short circuit" exists between the layers of a field-magnet coil, the car may start slowly and take more current than usual, and afterwards run at abnormal speed or blow the automatic switch.

A "short" on a field coil will generally cause a constant flare at the commutator, and the same effect will be produced if the strength of the magnetic field is reduced by one coil being wrongly connected with the other ones, or by a "ground" to the outer case.

Grounds in Controller.—When a ground occurs in a controller it may charge the handles and outer case; but if the outer case is in metallic contact with the rails the rush of current will blow the fuse or the automatic switch.

If the defective controller is first disconnected from circuit by removing its cables, the car can be driven from the other platform.

If the ground is on the "T" cable or finger it will only be necessary to remove this one cable, and if the defect is on the main contact drum it will not be necessary to remove any of the cables if the controller is left at "off" position and all fingers are clear.

Defects.

When the Car won't start on first power notch:

May be due to bad contact at controller fingers or cables.

May be broken circuit in rheostat if trouble is apparent at both controllers.

When the Car won't start until "full series" notch is reached:

May be defective rheostat or broken circuit on cables leading to rheostat.

When the Car won't start until "full series" is passed:

May be due to an open circuit in one of the motors or on cable leading to a motor. See that the brushes are pressing down on commutator.

If the fault lies in a motor the trouble will show at both controllers. If the car starts when the controller handle is midway between the series and parallel notches the open circuit will be in No. 2 motor; but if it does not start until the first parallel notch is reached the defect will be in No. 1 motor or its cables.

The trouble may be due to bad contact at controller fingers.

When the Car won't start on any notch:

May be caused by fuse melting, or switches may be off.

Power may be off line.

Try rear controller, and if trouble only shows itself at front controller it may be due to open circuit at "T" finger or cable.

Car may be standing on dirty rail.

When the Car won't speed up properly:

May be due to bad contact at controller fingers or cables.

If both controllers act in the same way it may be due to a defective rheostat or motor.

When the Car won't start and the car lamps refuse to light:

Power may be off line.

Cable from trolley head may be broken.

Car may be on dirty rail.

When the Car starts with unusual jerks, but runs all right on "full series" and "full parallel:"

May be due to short circuit in rheostat or rheostat cables.

Rheostat cables may be crossed and inserted in wrong terminals.

When the Car runs all right on series notches, but with only one motor, when on parallel notches:

May be due to fingers in controller not making contact to allow current from No. 1 motor to get to rails on parallel notches.

When the Car labours in starting, and runs faster than usual afterwards:

May be due to short circuit in field magnet coils.

When the Controller Handle cannot be moved from "off" position:

The "interlocking gear" may be sticking, and should be pulled clear of main drum.

When the Controller Handle cannot be moved past "full series" notch:

A motor "cut-out" may be out of place, or the "cut-out catch" may be fouling the main drum.

One of the fingers may be bent inwards.

When the Controller cannot be switched off:

Power must be turned off by main switch and car stopped at once.

A finger or loose screw may be catching on main drum, or the "arc shield" may be rubbing hard on it.

When a shock is got on touching Controller Case:

May be due to moisture getting into controller and allowing current to leak from fingers or cables.

Use rubber gloves or touch only wooden handle.

Car should be run to depôt as soon as convenient, especially if it is rear controller which is defective.

When Controller Fingers are defective:

Clean off burnt matter with file or emery-cloth.

A broken finger may be replaced by taking one from the rear controller.

When heavy flashes occur in a Controller:

Contacts require cleaning, or water has gained entrance.

Handle may be operated too slowly or not brought fully to notches.

When Controller Handle turns round easily without the usual decided "click" at the lines:

"Star wheel" roller and lever may be broken, or spring

may have given way. Handle should be moved carefully to lines when running car to depôt.

When Controller Handle is jammed on power or brake notches and car is being towed to the depôt:

Fingers on small reverse drums should be insulated by inserting a layer of paper under each, or brushes may be removed from motors in order to prevent any "electric brake" action when car is being towed home.

When the Automatic Switch or Fuse "blows" with Controller Handles at off position:

May be due to leak between fuse and "T" finger of controller.

Car should be towed to depôt, if it cannot be driven by rear controller after taking out "T" cable from front controller.

When the Automatic Switch blows immediately Controller Handle is moved to first power notch:

Probably due to a leak in controller on main drum or some finger.

When the Switch or Fuse blows when feeding up on series notches:

Probably due to ground in No. 1 motor or its cables. Motorman may be "feeding" too quickly.

When Switch or Fuse blows after passing full series:

Probably due to ground in No. 2 motor or its cables.

When a "ground" occurs at the Trolley Head or on the Trolley Cable:

If the trolley standard is connected direct to the rails by a "ground cable," the resulting rush of current may open the circuit-breaker in the power station and make the line dead. Pole should be removed from overhead wire at once, to allow power to be restored and car towed to depôt.

If signal lamps or other indicators are connected to the trolley standard, the leakage current will show its presence by operating these to warn motorman. Pole should be pulled down until passengers have been removed from top deck, after which it may be replaced and car run in.

When a Motor sparks badly at the brushes:

Brush may have jammed in holder, or may not be pressing hard enough on commutator.

Commutator may be oily or require cleaning.

Commutator may require re-turning to take out "flats" and rough spots.

Sparking may be due to short circuit in magnet coil or armature.

When a knocking or grinding noise is heard in a Motor:

Bearings may be worn and armature may be striking pole-pieces.

Armature binding wires may be slackened.

When the Bearings of a Motor become heated:

Oil should be freely applied and bearing allowed to cool off a little.

Run very slowly to terminus or depôt for examination.

When a Motor Gear-case falls down on roadway:

Gear-case may be held up from inside of car to allow car to be taken off main track.

Car may run in opposite direction without case actually jamming.

When the Gear Wheels run very noisily:

May require greasing, or may have slackened on axle.

Should be examined as soon as possible.

When a Car Axle breaks or becomes bent:

Car may be run to depôt with other motor, or may require another car to assist.

Broken axle may have to be held up from inside of car to prevent motor from sticking on road surface.

When the Car Wheels make a loud hammering noise at each revolution:

Due to "flats" on wheels. Flats are caused by allowing the wheels to "skid," and can often be prevented by a little care on the part of the motorman.

When Electric Brake fails to act properly on some notches:

May be due to bad contact at controller.

Fingers must be kept very clean and in good contact to obtain good brake action.

Commutators and brushes should be clean.

When Electric Brake acts very harshly on first brake notch:

May be due to "equaliser" fingers not making good contact.

The "equaliser" fingers are those which connect the positive ends of the magnet coils of the two motors

together on the brake notches, and are generally at the bottom of the controller.

When the Trolley Pole leaves the overhead wire frequently:

Tension springs may require tightening, or adjusting screw may be wrongly set and prevent pole from reaching wire properly.

Trolley head may be canted to one side and require adjustment.

When the Trolley Wheel chatters or squeals whilst running:

May require oil.

May have worn down too far, and requires renewing, otherwise it may damage overhead wire.

When one circuit of Lamps goes out:

May be due to burnt-out or defective lamp, which should be replaced.

A burnt-out lamp can be detected by its blackened appearance or broken filament.

Lamp fuse may have melted and requires renewal.

Bad contact may exist in the lighting switches, or an "open circuit" may have occurred in the lighting circuit wires or in a lamp holder.

When all the Car Lamps refuse to light:

Power may be off.

Lighting switches may be making bad contact.

Lighting fuses may have melted.

Car may be on dirty or "dead" rail.

When a Lamp Fuse blows:

Current may be getting to rails by some "ground" on the lighting wires, possibly at some of the outside lights which are exposed to the weather.

When Signal Bells refuse to ring:

May be defective bell or battery.

May be defective contact in "push."

When Signal Bells ring continuously:

May be due to short circuit on bell wires, or the contacts in one of the pushes may be sticking together.

If the former, disconnect bell from circuit by removing wires, and if the latter, screw off push cover and draw contact spring clear, or insert paper between. See that none of the pushes are jammed in.

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